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H. Balleur sculp.

NATURAL HISTORY,
GENERAL AND PARTICULAR,
BY THE
COUNT DE BUFFON.

TRANSLATED INTO ENGLISH,
ILLUSTRATED
WITH ABOVE THREE HUNDRED COPPER-PLATES,
AND OCCASIONAL
NOTES AND OBSERVATIONS,
By WILLIAM SMELLIE.
MEMBER OF THE ANTIQUARIAN AND ROYAL
SOCIETIES OF EDINBURGH.

THE THIRD EDITION,
IN NINE VOLUMES.

VOL. I.

L O N D O N:

PRINTED FOR A. STRAHAN, AND T. CADELL IN THE STRAND.

M DCC XCI.

TO THE
COUNT DE BUFFON,
&c. &c. &c.

S I R,

YOU did me honour by permitting me to address to you my Translation of your illustrious work ; and I am proud to exercise the privilege you so politely conferred upon me. The important Information it contains, and the Eloquence of its composition, joined to the Ingenuity, Taste, and Erudition, with which it abounds, induced me to

think that a Version of it into the English language, by diffusing the knowledge of Nature, would increase the number of her admirers. The task, it must be acknowledged, was arduous ; but your approbation and encouragement, by redoubling my vigour, diminished the difficulty of the labour.

It was with the liveliest pleasure that I received your communications respecting the valuable Performances you have already published, and concerning those great undertakings which now engage your attention. I failed not to announce to your friends in this country the advantages which Science and Literature have yet to expect from you ; and I need hardly observe, that their wishes and my own, for the accomplishment of your purposes, are in proportion to the greatness of your talents.

The

DEDICATION. v

The success which the Translation has met with, I impute to the celebrity of your name, and to the high value of the original.

I have the honour to be, with the most entire respect,

S I R,

Your most obedient, and

Most humble servant,

EDINBURGH,
May 10, 1781.

WILLIAM SMELLIE.

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P R E F A C E,

BY THE TRANSLATOR.

NATURAL HISTORY is the most extensive, and perhaps the most instructive and entertaining of all the sciences. It is the chief source from which human knowledge is derived. To recommend the study of it from motives of utility, were to affront the understanding of mankind. Its importance, accordingly, in the arts of life, and in storing the mind with just ideas of external objects, as well as of their relations to the human race, was early perceived by all nations in their progress from rudeness to refinement.

But, notwithstanding the great advantages to be derived from the knowledge of Nature, Aristotle is the only ancient writer on ZOOLOGY who merits attention. Instead of retailing fictions, or facts founded upon ignorance and credulity, he investigated the relations and differences which connect and distinguish the various tribes of animals. What had been only a chaos of detached, uncertain, and often fabulous, narrations and descriptions, he reduced into a scientific form, with a success so amazing, that, to this hour,

hour, no systematic view of animated beings has been attempted, the principles of which have not been adopted from Aristotle's history of animals. His analogies and distinctions are taken not only from the instruments of motion, the teeth, the eyes, the heart, and other external and internal organs of the body, to which the attention of our modern methodists has been chiefly confined, but from magnitude, figure, manners, faculties, and dispositions of mind. He attempted not to arrange and define every known species. This labour he left to men of less genius and more patience. His work consists entirely of philosophical dissertations on the general structure, manners, and dispositions of animals; and his particular facts are always employed to support the principles which he is endeavouring to establish.

Pliny and Ælian, though they had the illustrious example of Aristotle before them, produced nothing but crude collections, without discovering much taste, judgment, or knowledge of the subject.

From this period, till the voluminous Gesner and Aldrovandus appeared, the knowledge of Nature, like other branches of literature, was involved in the general gloom of ignorance and superstition. It was the object of these authors to amass every thing that had been said of animals by poets, shepherds, grammarians, philosophers, physicians, and old women. Their prolixity,

lixity, of course, is insufferable. Their labours, however, may be regarded as rude quarries, from which some valuable materials may be dug; but the expence of removing the rubbish will, perhaps, overbalance their intrinsic value.

In the same class, with little exception, may be ranked, Wotton, Belon, Rondeletius, Salvianus, Johnson, and a multitude of similar writers. They all transcribed, and sometimes abridged, the labours of their predecessors; but they uniformly lost sight of philosophy and science.

This race of phlegmatic writers was succeeded by our celebrated countrymen Mr. Ray and Mr. Willoughby, who were admirers of Nature, and lamented the slovenly dress in which she had been formerly exhibited. They knew the value of her treasures, and wished to show them in their native brilliancy. They rejected dubious and fictitious relations. They added, from observation and experiment, many new facts: They arranged animals under proper classes and subdivisions: They described with accuracy and precision: They pointed out the importance of the science, and recommended the study of it by the solidity and clearness of their views, and by the brevity and perspicuity of their compositions. This taste continued some time, and produced the Works of Reaumur, Trembley, Buffon, and similar publications.

From beginnings so prosperous, much was to be expected. But the excellency of method was

no sooner recognised, than the philosophy of the science was nearly extinguished by a profusion of new terms and arrangements. The justly celebrated Linnæus, by persevering industry, joined to the utility of his technical dictionary*, unfortunately turned the attention of most naturalists, though contrary to the learned author's design, from the great views of Nature to the humble ambition of system-making. It is needless to specify examples. Every philosopher must have observed, with regret, that inundation of methodical distributions which have successively appeared during the course of these last thirty or forty years. Since Linnæus's works were published, the attention of Naturalists has been principally occupied with criticising former arrangements, and fabricating new ones. The philosophy of the science has, of course, been almost totally neglected. Naturally history has been exhibited in its most forbidding aspect, which has limited the study of it to a few, and these often not of the most brilliant talents; for it has been remarked, that the parade of learning, resulting from technical phrases and definitions, allure some men to become what is called *great naturalists*, whose chief knowledge of Nature is the knack of being able to name, with facility, a great number of her productions.

* *Systēma Naturæ*, which, with regard to quadrupeds, can be considered in no other light.

This propensity for multiplying methodical distributions, and disputing about their respective merits, has brought much obloquy on the science of Nature. Men of sense perceive the folly of discussions concerning the local situation of an animal in a book. They consider the authors as learned triflers; and, what is worse, they are apt to regard a subject, which affords no better entertainment or information, as barren and unprofitable. To no other source can we ascribe the following sentiments, so frequently expressed by men of no inconsiderable talents: 'That natural historians have seldom discovered extensive views; that they confine their chief attention to the mere technical part of the science; that they rarely take notice of manners and instincts, or the causes and œconomy of animal action; and that they never pursue these great and useful objects with a degree of taste and philosophical accuracy, proportioned to the importance of the subject.' These strictures are common: I wish that they had no foundation in truth.

In natural history, two ends only can be attained by system. Both of them are useful; but they are extremely different in their kinds. System may be employed either to facilitate the distinction of objects, or to ascertain their relations in the scale of being.

The first species of system, it is obvious, must consist entirely of a series of external or internal

nal characters. It is of little moment, whether the objects ranked under particular ORDERS be mutually connected; because, if we may judge from the many laborious, but abortive, attempts which have been made, Nature seems not to have expressed such connections in characters recognisable by our senses. A system so limited in its principles and design, can never assume any other form than that of a technical index or dictionary. If the general and particular characters be so marked, that a student, after learning the divisions and language of the author, can investigate the proper names of the objects presented to him, this system is perfect; because its sole and primary intention is fulfilled.

Were every naturalist of the same sentiments with regard to this point, many incumbrances, which now load the science, would be removed; the tyro would not be disgusted and retarded by an infinity of synonyms; natural history would acquire a more simple and intelligible form; and the number of its votaries would soon be augmented.

The second species of system is more elevated and sublime. But, as it includes the whole philosophy of Nature, it requires a depth of judgment, a superiority of genius, an extent of knowledge, which are seldom united in the same person. Natural objects are wonderfully diversified in their structure, œconomy, and faculties. But, in these, as well as in many other circumstances,

stances, they are no less wonderfully connected. Here, then, are foundations for constructing the system of Nature. To mark the distinctions, to investigate the relations, to ascertain the great chain that unites the numerous tribes which people and adorn the universe, would demand talents superior, perhaps, to those of humanity. We ought not, however, to despair. Hardly any hands can be set to the combined force of different minds acting successively upon the same subject. ~~Still~~ something has already been done. More may in time appear: Nature, in some future period, may happily unite philosophy and Natural History, a phenomenon which has hitherto been but partially exhibited.

Among those authors, whether ancient or modern, who have contributed to unfold the philosophy of Natural History, the COUNT DE BUFFON holds the most distinguished rank. This learned and eloquent writer has introduced into his subjects a greater variety of disquisition, and given more comprehensive views of Nature, than any preceding or contemporary historian. His facts are, in general, collected with judgment and fidelity; and his reasonings and inferences are not only bold and ingenious, but adorned with all the beauties of expression, and all the charms of novelty. They every where lead to reflections which are momentous and interesting. They expand the mind and banish prejudices. They create an elevation of thought, and

and cherish an ardour of inquiry. They open many great and delightful prospects of the œconomy of Nature, of the alterations and accidents to which she is liable, of the causes of her improvement or degeneration, and of the general relations that connect the whole, and give rise to all the diversities which characterise and constitute particular orders of existence.

The original work, of which I have attempted a translation, was undertaken, and carried into execution under the munificent encouragement of a great monarch. The design was to compose a history which should record not only every phænomenon in the universe that was already known, but to examine, describe, and delineate from the life, all the animals which could be procured by royal influence. A plan so extensive required the joint operation of, at least, two persons: the one to compose the historical part, the other to dissect and minutely describe every animal, both native and foreign, that should be obtained. The literary character and philosophic talents of the COUNT DE BUFFON pointed him out for the execution of the first department; and the acuteness and anatomical skill of M. DAUBENTON recommended him for that of the second.

Three volumes of this great work were given to the public in the year 1749. These volumes exhibited such displays of learning, taste, genius, and eloquence, as procured to the author un-
common

common admiration, and excited a strong and general desire for the completion of his plan; which, however, from various causes, was not accomplished till the year 1767.

The COUNT DE BUFFON, in the year 1776, favoured the world with a supplementary volume to his history of quadrupeds, which, beside an ingenious dissertation on Mules, contains the history and figures of several new animals, and valuable additions to most of those described in the original publication.

It would be improper to enter more minutely into the history or contents of this magnificent work. Such is the fertility of the author's genius, and such his ardour for philosophic inquiry, that, when treating of the most common animals, he often astonishes his reader with the profoundness of his remarks, and the beauty of his analogical discussions.

But, though the publication was a great acquisition to literature; yet the high price of SIXTEEN GUINEAS, which was an unavoidable consequence of its splendour, and of the prodigious number of its elegant engravings, confined its utility to men of opulence. Sensible of this inconvenience, the COUNT DE BUFFON, a few years ago, published an edition in 12mo; and, to bring it within the reach of common purchasers, he excluded from it the long and minute anatomical dissections and mensurations.

After this short sketch of the COUNT DE BUFFON'S History of Nature, it may seem strange

that no decent translation of it has hitherto appeared in the English language. To such an undertaking, the great expence of the engravings was one solid objection. Another arose from the vast variety of learning employed by the author. When to these are added the exuberance of his fancy, the eloquence and force of his diction, the delicacy and minuteness of his disquisitions, we should rather wonder how any man could reconcile himself to a task so laborious, and which required the union of such diversified talents.

* * *

This translation comprehends what is contained in the original fifteen volumes in quarto, together with the supplementary volume to the history of quadrupeds, except the description of the King's cabinet, the dry and uninteresting anatomical dissections and mensurations, which can be of little use but to professed anatomists, and have been properly omitted by the author in the last Paris edition. The method of studying Natural History; the reprehension of methodical distributions; and the mode of describing animals, are likewise omitted. The chief intention of these discourses is to ridicule the authors of systematic arrangements, and particularly the late ingenuous and indefatigable Sir Charles Linnaeus, whose zeal and labours in promoting the investigation of natural objects merit the highest applause.

applause. There is a stronger reason for this omission: The same remarks and arguments are, perhaps, too frequently repeated in the history of particular animals.

To render this English version more valuable, the translator has added short distinctive descriptions to each species of quadrupeds. For these he has been indebted to the labours of the learned and ingenious Mr. Pennant. Beside these useful additions, the synonyms, and the generic and specific characters given by Linnæus, Klein, Brisson, and other naturalists, are subjoined to the description of each species.

Where the author commits mistakes, or where he recommends practices, regarding the management of particular animals, which differ from those observed in this country, the translator has taken the liberty of animadverting upon such passages in notes: But he has seldom taken any notice of peculiar theories or doctrines. These must rest upon the facts and arguments employed by the author. It was not the intention of the translator to write a commentary upon his original.

The great variety of subjects discussed by the Count de Buffon, has already been mentioned. It is almost unnecessary to remark, that every subject demands a peculiar style. A bare enumeration of facts, or descriptions of the dimensions, figure, and colour of animals, admit of no other ornament than that of perspicuity. Topics of philosophy and argument require a higher and

more figurative expression: And addresses to the passions, and the finer feelings of men, give full scope to the exercise of genius and of taste. Of these different species of writing, the examples are numerous in the works of the **COUNT DE BUFFON**. The translator has endeavoured to follow the original, as far as his abilities would permit. The degree of success he has attained must be submitted to the partial determination of the public. He shall only say, that his apprehensions, though he is conscious of no voluntary negligence, are much greater than his hopes.

N. B. Since the first edition was printed, the Count de Buffon has published another supplementary volume. It consists chiefly of curious and interesting facts with regard to the history of the earth. These the Translator has added in a separate volume, which, to accommodate the purchasers of the former edition, he has directed to be sold by itself.

* * In the dimensions of animals, the translator has retained the French measures. The differences between the foot or inch of England and France are so inconsiderable, when applied to individual animals, that he thought it unnecessary to reduce them to the precise English standard, especially as the dimensions are English in the descriptions added in the notes.

THE
HISTORY AND THEORY
OF THE
ART H.

THE figure of the earth*, its motions, or the external relations which subsist between it and the other parts of the universe, belong not to our present inquiry. It is the internal structure of the globe, its form and manner of existence, which we here propose to examine. The general history of the earth ought to precede that of its productions. Details of particular facts relating to the oeconomy and manners of animals, or to the culture and vegetation of plants, are not, perhaps, so much the objects of natural history, as general deductions from the observations that have been made upon the different materials of which the earth itself is composed; as its heights, depths, and inequalities; the motions of the sea, the direction of mountains, the situation of rocks and quarries, the rapidity and effects of currents in the ocean, &c.

* See subsequent proofs of the theory of the earth, art. I.

2 THEORY OF THE EARTH.

This is the history of Nature at large, and of her principal operations, by which every other inferior or less general effect is produced. The theory of these effects constitutes what may be called the primary science, upon which a precise knowledge of particular appearances, as well as of terrestrial substances, solely depends. This species of science may be considered as appertaining to physics; but, is not all physical knowledge, where system is excluded, part of the history of nature?

In subjects of an extensive kind, the relations of which it is difficult to trace, where some facts are but partially known, and others obscure, it is more easy to form a fanciful system, than to establish a rational theory. Thus the theory of the earth has never hitherto been treated but in a vague and hypothetical manner. I shall, therefore, exhibit a cursory view only of the notions of some authors who have written upon this subject.

The first hypothesis I shall mention is more conspicuous for its ingenuity than solidity. It is the production of an English astronomer*, who was an enthusiastic admirer of Sir Isaac Newton's system of philosophy. Convinced that every possible event depends upon the motions and direction of the stars, he endeavours to prove, by means of mathematical calculations,

* Whiston. See the proofs, art. II.

that all the changes this earth has undergone have been produced by the tail of a comet.

For another hypothesis we are indebted to a heterodox divine*, whose brain was so fully impregnated with poetical illusions, that he imagined he had seen the universe created. After telling us the state of the earth when it first sprang from nothing, what changes have been introduced by the deluge, what the earth has been, and what it now is, he assumes the prophetic style, and predicts what will be its condition after the destruction of the human kind.

A third writer†, a man of more extensive observation than the two former, but equally crude and confused in his ideas, explains the principal appearances of the globe by the aid of an immense abyss in the bowels of the earth, which, in his estimation, is nothing but a thin crust inclosing this vast ocean of fluid matter.

These hypotheses are all constructed on tottering foundations. The ideas they contain are indistinct, the facts are confounded, and the whole is a motley jumble of physics and fable. They, accordingly, have never been adopted but by men who embrace opinions without examination, and who, incapable of distinguishing the degrees of probability, are more deeply impressed with marvellous chimeras than with the genuine force of truth.

* Burnet. See proofs, art. III.

† Woodward. See proofs, art. IV.

4 THEORY OF THE EARTH.

My ideas on this subject will be less extraordinary, and may even appear unimportant, when compared with the grand systems of such hypothetical writers. But it should not be forgotten, that it is the business of an historian to describe, not to invent; that no gratuitous suppositions are to be admitted in subjects which depend upon fact and observation; and that, in historical compositions, the imagination cannot be employed, except for the purpose of combining observations, of rendering facts more general, and of forming a connected whole, which presents to the mind clear ideas, and probable conjectures: I say, probable; for it is impossible to give demonstrative evidence on this subject. Demonstration is confined to the mathematical sciences. Our knowledge in physics and natural history depends entirely on experience, and is limited to the method of reasoning by induction.

With regard to the history of the earth, therefore, we shall begin with such facts as have been universally acknowledged in all ages, not omitting those additional truths which have fallen within our own observation.

The surface of this immense globe exhibits to our observation heights, depths, plains, seas, marshes, rivers, caverns, gulfs, volcano's; and, on a cursory view, we can discover, in the disposition of these objects, neither order nor regularity. If we penetrate into the bowels of the earth,

earth, we find metals, minerals, stones, bitumens, sands, earths, waters, and matter of every kind, seemingly placed by mere accident, and without any apparent design. Upon a nearer and more attentive inspection, we discover sunk mountains*, caverns filled up, shattered rocks, whole countries swallowed up, new islands emerged from the ocean, heavy substances placed above light ones, hard bodies inclosed within soft bodies; in a word, we find matter in every form, dry and humid, warm and cold, solid and brittle, blended in a chaos of confusion, which can be compared to nothing but a heap of rubbish, or the ruins of a world.

These ruins, however, we inhabit with perfect security. The different generations of men, of animals, and of plants, succeed one another without interruption: The productions of the earth are sufficient for their sustenance; the motions of the sea, and the currents of the air, are regulated by fixed laws†; the returns of the seasons are uniform, and the rigours of winter invariably give place to the verdure of the spring. With regard to us, every thing has the appearance of order: The earth, formerly a chaos, is now a tranquil, an harmonious, a delightful habitation, where all is animated and governed by

* See Senec. *Quæst.* lib. 6. cap. 21. Strab. *Geog.* lib. 1. Orosius, lib. 2. cap. 18. Plin. lib. 2. cap. 19. *Hist. de l'acad. des sciences*, année 1708, p. 23.

† See the proofs, art. XIV.

6 THEORY OF THE EARTH.

such amazing displays of power and intelligence, as fill us with admiration, and elevate our minds to the contemplation of the great Creator.

But let us not decide precipitantly concerning the irregularities on the surface of the earth, and the apparent disorder in its bowels: We shall soon perceive the utility, and even the necessity of this arrangement. With a little attention, we shall perhaps discover an order of which we had no conception, and general relations that cannot be apprehended by a slight examination. Our knowledge, indeed, with regard to this ~~subject~~ subject, must always be limited. We are entirely unacquainted with many parts of the surface of this globe*, and have partial ideas only concerning the bottom of the ocean, which, in many places, has never been sounded. We can only penetrate the rind of the earth. The greatest caverns†, the deepest mines‡, descend not above the eight thousandth part of its diameter. Our judgment is therefore confined to the upper stratum, or mere superficial part. We know, indeed, that, bulk for bulk, the earth is four times heavier than the sun: We likewise know the proportion its weight bears to that of the other planets. But still this estimation is only relative. We have no standard. Of the real weight of the materials we are so ignorant, that the internal part of the globe may be either

* See proofs, art. VI. † Phil. trans. abridged, vol. ii. p. 323. ‡ Boyle's works, vol. iii. p. 232.

a void space, or it may be composed of matter a thousand times heavier than gold. Neither is there any method of making farther discoveries on this subject. It is even with difficulty that rational conjectures can be formed*.

We must therefore confine ourselves to an accurate examination and description of the surface of the earth, and of such inconsiderable depths as we have been able to penetrate. The first object which attracts attention, is that immense collection of waters with which the greatest part of the globe is covered. These waters occupy the lowest grounds; their surface is always level; and, notwithstanding their uniform tendency to equilibrium and rest, they are kept in perpetual agitation by a powerful agent †, which counteracts their natural tranquillity, which communicates to them a regular periodic motion, alternately elevating and depressing their waves, and which produces a concussion or vibration in the whole mass, even to the most profound depths. This motion of the waters is coëval with time, and will endure as long as the sun and moon, by which it is produced.

In examining the bottom of the sea, we perceive it to be equally irregular as the surface of the dry land ‡. We discover hills and valleys, plains and hollows, rocks and earths of every

* See proofs, art. I.

† Proofs, art. XII.

‡ Proofs, art. XIII.

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kind*: We discover, likewise, that islands are nothing but the summits of vast mountains, whose foundations are buried in the ocean †; we find other mountains whose tops are nearly on a level with the surface of the water; and rapid currents which run contrary to the general movement ‡. These currents sometimes run in the same direction; at other times their motion is retrograde ||; but they never exceed their natural limits, which seem to be as immutable as those which bound the efforts of land-rivers. On one hand, we meet with tempestuous regions, where the winds blow with irresistible fury, where the heavens and the ocean, equally convulsed, are mixed and confounded in the general shock; violent intestine motions, tumultuous swellings§, water-spouts**, and strange agitations, produced by volcano's, whose mouths, though many fathoms below the surface, vomit forth torrents of fire, and push, even to the clouds, a thick vapour, composed of water, sulphur, and bitumen; and dreadful gulphs or whirlpools††, which seem to attract vessels for no other purpose than to swallow them up. On the other hand, we discover vast regions of an opposite nature, always smooth and calm, but

* See M. Buache's chart of the depths of the ocean between Africa and America.

† Varenii Geog. gen. p. 218.

‡ Proofs, art. XIII.

|| Varen. p. 140. and Voyages de

Pirard, p. 137.

§ Shaw's travels.

** Proofs, art. XVI.

†† The Maelstrom in the Norwegian sea.

equally

equally dangerous to the mariner *. Here the winds never exert their force; the nautical art is of no utility; the becalmed voyagers must remain immoveably fixed, till death relieve them from misery. To conclude, directing our eyes toward the southern or northern extremities of the globe, we discover huge masses of ice †, which, detaching themselves from the polar regions, advance, like floating mountains, to the more temperate climates, where they dissolve and vanish from our view ‡.

Beside these grand objects, the ocean presents us with myriads of animated beings, almost infinite in variety: Some, clothed in light scales, swim with amazing swiftness; others, loaded with thick shells, trail heavily along, leaving their traces in the sand: To others Nature has given fins resembling wings, with which they support themselves in the air, and fly before their enemies to considerable distances. Lastly, the sea gives birth to other animals, which, totally deprived of motion, live and die immoveably fixed to the same rocks: All, however, find abundance of food in this fluid element. The bottom of the ocean, and the shelving sides of rocks, produce plentiful crops of plants of many different species; its soil is composed of sand, gravel, rocks, and shells; in some places, it is a fine clay, in others, a compact earth; and, in general, the bottom of the sea has an

* The calms and tornados in the Æthiopian sea.

† Proofs, art. VI. and X, ‡ See Buache's chart, 1739.

exact resemblance to the dry land which we inhabit.

Let us next take a view of the land: What prodigious differences take place in different climates! What a variety of soils! What inequalities in the surface! But, upon a more attentive observation, we shall perceive, that the great chains of mountains lie nearer the equator than the poles*; that, in the Old Continent, their direction is more from east to west than from south to north; and that, on the contrary, in the New Continent, they extend more from north to south than from east to west. But, what is still more remarkable, the figure and direction of these mountains, which have a most irregular appearance†, correspond so wonderfully, that the *prominent* angles of one mountain are constantly opposite to the *concave*‡ angles of the neighbouring mountain ||, and of equal dimensions, whether they be separated by an extensive plain, or a small valley. I have further remarked, that opposite hills are always nearly of the same height; and that mountains generally occupy the middle of continents, islands, and promontories, dividing them by their greatest lengths§. I have likewise traced the courses of the principal rivers, and find that their direction is nearly perpendicular to the sea-coasts into which they empty themselves; and that, during the

* Proofs, art. IX. † Ibid. art. IX. XII. ‡ *Saliant*
and *re-entering* angles; Muller's fortification. || *Lettres*
Phil. de Bourguet, p. 181. § Varen. Geog. p. 69.

greatest part of their courses, they follow the direction of the mountains from which they derive their origin *. The sea-coasts are generally bordered with rocks of marble and other hard stones, or rather with earth and sand accumulated by the waters of the sea, or brought down and deposited by rivers. In opposite coasts, separated only by small arms of the sea, the different strata or beds of earth are of the same materials †. I find that volcano's never exist but in high mountains ‡; that a great number of them are entirely extinguished; that some are connected with others by subterranean passages, and their eruptions not unfrequently happen at the same time §. There are similar communications between certain lakes and seas. Some rivers suddenly disappear ¶, and seem to precipitate themselves into the bowels of the earth. We likewise find certain mediterranean or inland seas, which constantly receive, from many and great rivers, prodigious quantities of water, without any augmentation of their bounds, probably discharging, by subterraneous passages, all these extraneous supplies. It is likewise easy to distinguish lands which have been long inhabited, from those new countries where the earth appears in a rude state, where the rivers are full of cataracts, where the land is either nearly overflowed with water, or burnt up with drought, and where every place

* Proofs, art. X. † Ibid. art. VII. ‡ Ibid. art. XVI.
 § Kircher Mund. subter. in praef. ¶ Varen. Geog. p. 43.

capable of producing trees is totally covered with wood.

Proceeding in our examination, we discover that the upper stratum of the earth is universally the same substance *; that this substance, from which all animals and vegetables derive their growth and nourishment, is nothing but a composition of the decayed parts of animal and vegetable bodies, reduced into such small particles that their former organic state is not distinguishable. Penetrating a little deeper, we find the real earth, beds of sand, lime-stone, clay, shells, marble, gravel, chalk, &c. These beds are always parallel to each other †, and of the same thickness through their whole extent. In neighbouring hills, beds or strata of the same materials are uniformly found at the same levels, though the hills be separated by deep and large valleys. Strata of every kind, even of the most solid rocks, are uniformly divided by perpendicular fissures ‡. Shells, skeletons of fishes, marine plants, &c. are often found in the bowels of the earth, and on the tops of mountains ||, even at the greatest distances from the sea. These shells, fishes, and plants, are exactly similar to those which exist in the ocean. Petrified shells are to be met with, almost every where, in prodigious quantities: They are not only inclosed in rocks of marble and lime-stone, as

* Proofs, art. VII.

† Ibid. and Woodward, p. 41. &c.

‡ Proofs, art. VIII.

|| Proofs, art. VIII.

well as in earths and clays, but are actually incorporated and filled with the very substances in which they are inclosed. In fine, I am convinced, by repeated observation, that marbles, lime-stones, chalks, marles, clays, sand, and almost all terrestrial substances, wherever situated, are full of shells and other spoils of the ocean*.

Having enumerated these facts, let us try what conclusions can be drawn from them.

The changes which the earth has undergone during the last two or three thousand years are inconsiderable, when compared with the great revolutions which must have happened in those ages that immediately succeeded the création. For, as terrestrial substances could only acquire solidity by the continued action of gravity, it is easy to demonstrate, that the surface of the earth was at first much softer than it is now; and, consequently, that the same causes, which at present produce but slight and almost imperceptible alterations during the course of many centuries, were then capable of producing very great revolutions in a few years. It appears, indeed, to be an incontrovertible fact, that the dry land which we now inhabit, and even the summits of the highest mountains, were formerly covered with the waters of the sea; for shells, and other marine bodies, are

Steno, Woodward, Ray, Bourguet, Scheuchzer, Phil. Trans. Mem. de l'Acad. &c.

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still found upon the very tops of mountains. It likewise appears, that the waters of the sea have remained for a long track of years upon the surface of the earth; because, in many places, such immense banks of shells have been discovered, that it is impossible so great a multitude of animals could exist at the same time. This circumstance seems likewise to prove, that, although the materials on the surface of the earth were then soft, and, of course, easily disunited, moved, and transported, by the waters; yet these transportations could not be suddenly effected. They must have been gradual and successive, as sea-bodies are sometimes found more than 1000 feet below the surface. Such a thickness of earth or of stone could not be accumulated in a short period. Although it should be supposed, that, at the deluge, all the shells were transported from the bottom of the ocean, and deposited upon the dry land; yet, beside the difficulty of establishing this supposition, it is clear, that, as shells are found incorporated in marble and in the rocks of the highest mountains, we must likewise suppose, that all these marbles and rocks were formed at the same time, and at the very instant when the deluge took place; and that, before this grand revolution, there were neither mountains, nor marbles, nor rocks, nor clays, nor matter of any kind, similar to what we are now acquainted with, as they all, with few exceptions, contain shells,
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and other productions of the ocean. Besides, at the time of the universal deluge, the earth must have acquired a considerable degree of solidity, by the action of gravity for more than sixteen centuries. During the short time the deluge lasted, therefore, it is impossible that the waters should have overturned and dissolved the whole surface of the earth, to the greatest depths that mankind have been able to penetrate.

But, not to insist longer on this point, which shall afterwards be more fully canvassed, I shall confine myself to known and established facts. It is certain, that the waters of the sea have, at some period or other, remained for a succession of ages upon what we now know to be dry land; and, consequently, that the vast continents of Asia, Europe, Africa, and America, were then the bottom of an immense ocean, replete with every thing which the present ocean produces. It is likewise certain, that the different strata of the earth are horizontal, and parallel to each other*. This parallel situation must, therefore, be owing to the operation of the waters, which have gradually accumulated the different materials, and given them the same position that water itself invariably assumes. The horizontal position of strata is almost universal: In plains, the strata are exactly horizontal. It is only in the mountains that they are inclined to the horizon; because they have ori-

* Proofs, art. VII.

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ginally been formed by sediments deposited upon an inclined base. Now, I maintain, that these strata must have been gradually formed, and that they are not the effect of any sudden revolution; because nothing is more frequent than strata composed of heavy materials placed above light ones, which never could have happened, if, according to some authors, the whole had been blended and dissolved by the deluge, and afterwards precipitated. On this supposition every thing should have had a different aspect from what now appears. The heaviest bodies should have descended first, and every stratum should have had a situation corresponding to its specific gravity. In this case we should not have seen solid rocks or metals placed above light sand, nor clay under coal.

Another circumstance demands our attention. No cause but the motion and sediments of water could possibly produce the regular position of the various strata of which the superficial part of this earth is composed. The highest mountains consist of parallel strata, as well as the lowest valleys. Of course, the formation of mountains cannot be imputed to the shocks of earthquakes, or to the eruptions of volcano's. Such small eminences as have been raised by volcano's or convulsions of the earth, instead of being composed of parallel strata, are mere masses of weighty materials, blended together in the
utmost

utmost confusion*. But this parallel and horizontal position of strata must necessarily be the operation of a uniform and constant cause.

We are, therefore, authorised to conclude, from repeated and incontrovertible facts and observations, that the dry and habitable part of the earth has for a long time remained under the waters of the sea, and must have undergone the same changes which are at present going on at the bottom of the ocean. To discover what has formerly happened to the dry land, let us examine what passes in the bottom of the sea; and we shall soon be enabled to make some rational conclusions with regard to the external figure and internal constitution of the earth.

The ocean, from the creation of the solar system, has been constantly subject to a regular flux and reflux. These motions, which happen twice in twenty-four hours, are principally occasioned by the action of the moon, and are greater in the equatorial regions than in other climates. The earth likewise performs a rapid motion round its axis, and, consequently, has a centrifugal force, which is also greatest at the equator. This last circumstance, independent of actual observations, proves, that the earth is not a perfect sphere, but that it must be more elevated under the equator than at the poles. From these two combined causes, the tides, and the motion

* Proofs, art. XVII.

of the earth, it may be fairly concluded, that, although this globe had been originally a perfect sphere, its diurnal motion, and the ebbing and flowing of the tides, must necessarily, in a succession of time, have elevated the equatorial parts, by gradually carrying mud, earth, sand, shells, &c. from other climates, and depositing them at the equator*. On this supposition, the greatest inequalities on the surface of the earth ought to be, and, in fact, are found, in the neighbourhood of the equator. Besides, as the alternate motion of the tides has been constant and regular since the existence of the world, is it not evident, that, at each tide, the water carries from one place to another a small quantity of matter which falls to the bottom as a sediment, and forms those horizontal and parallel strata that every where appear? The motion of the waters, in the flux and reflux, being always horizontal, the matter transported by them must necessarily take the same parallel direction after it is deposited.

To this reasoning, it may be objected, that, as the flux is equal to, and regularly succeeded by, the reflux, the two motions will balance each other; or, that the matter brought by the flux will be carried back by the reflux; and, consequently, that this cause of the formation of strata must be chimerical, as the bottom of the ocean can never be affected by a uniform alternate motion

* Proof, art. XII.

of the waters; far less could this motion change its original structure, by creating heights, and other inequalities.

But, in the first place, the alternate motion of the waters is by no means equal; for the sea has a continual motion from east to west: Besides, the agitations occasioned by the winds produce great inequalities in the tides. It will likewise be acknowledged, that, by every motion in the sea, particles of earth, and other materials, must be carried from one place, and deposited in another; and that these collections of matter must assume the form of parallel and horizontal strata. Farther, a well-known fact will entirely obviate this objection. On all coasts, where the ebbing and flowing are discernible*, numberless materials are brought in by the flux, which are not carried back by the reflux. The sea gradually increases on some places, and recedes from others, narrowing its limits, by depositing earth, sand, shells, &c. which naturally take a horizontal position. These materials, when accumulated and elevated to a certain degree, gradually shut out the water, and remain for ever in the form of dry land.

But, to remove every doubt concerning this important point, let us examine more closely the practicability of a mountain's being formed at the bottom of the sea, by the motion and se-

* Proofs, art. XIX.

diments of the water. On a high coast which the sea washes with violence during the flow, some part of the earth must be carried off by every stroke of the waves. Even where the sea is bounded by rock, it is a known fact, that the stone is gradually wasted by the water*; and consequently, that small particles are carried off by the retreat of every wave. Those particles of earth or stone are necessarily transported to some distance. Whenever the agitation of the water is abated, the particles are precipitated in the form of a sediment, and lay the foundation of a first stratum, which is either horizontal, or inclined, according to the situation of the surface upon which they fall. This stratum will soon be succeeded by a similar one, produced by the same cause; and thus a considerable quantity of matter will be gradually amassed, and disposed in parallel beds. In process of time, this gradually accumulating mass will become a mountain in the bottom of the sea, exactly resembling, both in external and internal structure, those mountains which we see on the dry land. If there happened to be shells in that part of the bottom of the sea where we have supposed the sediments to be deposited, they would be covered, filled, and incorporated, with the deposited matter, and form a part of the general mass. These shells would be lodged in different parts of the mountains, correspond-

* See Shaw's travels.

ing to the times they were deposited. Those which lay at the bottom, before the first stratum was formed, would occupy the lowest station; and those which were afterwards deposited, would be found in the more elevated parts.

In the same manner, when the bottom of the sea, at particular places, is troubled by the agitation of the waters, earth, clay, shells, and other matter, must necessarily be removed from these parts, and deposited elsewhere. For we are assured by divers, that the bottom of the sea, at the greatest depths to which they descend*, is so strongly affected by the agitation of the water, that earth, clay, and shells, are removed to great distances. Transportations of this kind must, therefore, be constantly going on in every part of the ocean; and the matters transported, after subsiding, must uniformly raise eminences similar, in every respect, to the composition and structure of our mountains. Thus the motions produced by the flux and reflux, by winds and currents, must uniformly create inequalities in the bottom of the ocean.

Farther, we must not imagine that these matters cannot be carried to great distances, since we daily find grain, and other productions of the East and West Indies, arriving on our coasts†. These bodies are, indeed, specifically lighter than water; and the other substances

* Boyle's works, vol 3. p. 232. † Particularly on the coasts of Scotland and of Ireland. See Ray's Discourses.

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are specifically heavier. Still, however, as they are reduced to an impalpable powder, they may be kept long suspended in the water, and, of course, transported to any distance.

It has been conceived, that the agitation produced by the winds and tides is only superficial, and affects not the bottom, especially when it is very deep. But it ought to be remembered, that, whatever be the depth, the whole mass is put in motion by the tides at the same time; and that, in a fluid globe, this motion would be communicated even to the centre. The power which occasions the flux and reflux is penetrating; it acts equally upon every particle of the mass. Hence the quantity of its force, at different depths, may be determined by calculation. Indeed, this point is so certain, that it admits not of dispute.

We cannot, therefore, hesitate in pronouncing, that the tides, the winds, and every other cause of motion in the sea, must produce heights and inequalities in its bottom; and that these eminences must uniformly be composed of regular strata, either horizontal or inclined. These heights will gradually augment; like the waves which formed them, they will mutually respect each other; and if the extent of the base be great, in a track of years they will form a vast chain of mountains. Whenever eminences are formed, they interrupt the uniform motion of the waters, and produce new motions, known
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by the name of currents. Between two neighbouring heights in the bottom of the ocean, there must be a current*, which will follow their common direction, and, like a river, cut a channel, the angles of which will be alternately opposite through the whole extent of its course. These heights must continually increase; for, during the flow, the water will deposite its ordinary sediment upon their ridges, and the waters which are impelled by the current will force along, from great distances, quantities of matter, which will subside between the hills, and, at the same time, scoop out a valley with corresponding angles at their foundation. Now, by means of these different motions and sediments, the bottom of the ocean, though formerly smooth, must soon be furrowed, and interspersed with hills and chains of mountains, as we actually find it at present. The soft materials of which the eminences were originally composed, would gradually harden by their own gravity. Such of them as consisted of sandy and crystalline particles, would produce those enormous masses of rock and flint in which we find crystals and other precious stones. Others composed of stony particles mixed with shells, give rise to those beds of lime-stone and marble, in which vast quantities of sea shells are still found incorporated. Lastly, all our beds of marble and chalk have derived their origin from particles of shells mix-

* Proofs, art. XIII.

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ed with a pure earth, collected and deposited at particular places in the bottom of the sea. All these substances are disposed in regular strata; they all contain heterogeneous matter, and vast quantities of sea-bodies situated nearly in proportion to their specific gravities. The lighter shells are found in chalk; the heavier in clay and lime-stone. These shells are uniformly filled with the matter in which they are found, whether it be stone or earth. This is an incontestible proof, that they have been transported along with the matter that fills and surrounds them, and that this matter was then in the form of an impalpable powder. In a word, all those substances, the horizontal situation of which has arisen from the waters of the sea, invariably preserve their original position.

It may here be objected, that most hills, the summits of which consist of solid rocks, or of marble, are founded upon small eminences, composed of less heavy materials, such as clay or light sand, the strata of which commonly extend over the neighbouring plains. If the above theory be just, what could bring about an arrangement so singular so contrary, to the laws of gravity? But this phænomenon admits of a natural and easy explication. The waters would operate first upon the upper stratum either of coasts or the bottom of the sea: This upper stratum consists generally of clay or sand; and these light substances, being carried
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off and deposited previous to the more dense and solid, they would of course form small eminences, and become foundations for the more heavy particles to rest upon. After the light superficial substances were removed, the harder and more ponderous would next be subjected to the attrition of the water, reduced to a fine powder, and carried off and deposited above the hillocks of sand or clay. These small stony particles would, in a succession of ages, form those solid rocks which we now find on the tops of hills and mountains. As particles of stone are heavier than sand or clay, it is probable that they were originally covered and pressed by superior strata of considerable depth; but that they now occupy the highest stations, because they were last transported by the waves.

To confirm this reasoning, let us investigate more minutely the situation of those materials which compose the superficial part of the globe, the only part of which we have any adequate knowledge. The different strata of stones in quarries are almost all horizontal, or regularly inclined. Those founded upon hard clay, or other solid matter, are evidently horizontal, especially in plains. The disposition of quarries, where flint or brownish free-stone are found in detached portions, is indeed less regular. But even here the uniformity of nature is not interrupted; for the horizontal or regularly inclining position of the strata is apparent in granite and
brown

brown free-stone, wherever they exist in large connected masses. This position is universal, except in flint and brown free-stone in small detached portions, substances the formation of which we shall demonstrate to have been posterior to those just now mentioned. The strata of granite, vitrifiable sand, clays, marbles, calcareous stones, chalk, and marls, are always parallel or equally inclined. In these the original formation is easily discoverable; for the strata are exactly horizontal, and very thin, being placed above each other like the leaves of a book. Beds of sand, of soft and hard clay, of chalk, and of shells, are likewise either horizontal or uniformly inclined. Strata of every kind preserve the same thickness through their whole extent, which is often many leagues, and might, by proper observations, be traced still farther. In a word, the disposition of strata, as deep as mankind have hitherto penetrated, is the same.

Those beds of sand and gravel which are washed down from mountains, must, in some measure, be excepted from the general rule. They are sometimes of a considerable extent in valleys, and are situated immediately under the soil or first stratum. In plains, they are level, like the more antient and interior strata. But near the bottom, or upon the ridges of hills, they have an inclination corresponding to that of the ground upon which they have been deposited. As these beds of sand and gravel are

formed

formed by rivers and brooks, which, especially in the valleys, often change their channels, it is not surprising that such beds should be so frequent. A small rivulet is sufficient, in a course of time, to spread a bed of sand or gravel over a very large valley. In a champaign country, surrounded with hills, whose bases, as well as the upper stratum of the plain, consisted of a hard clay, I have often observed, that, above the origin of the brooks or rivers, the clay was situated immediately under the vegetable stratum; but, in the low grounds, there was a stratum of sand, about a foot thick, above the clay, and extending to a great distance from the banks of the rivers. The strata formed by rivers are not very antient; they are easily distinguished by their frequent interruptions, and the inequality of their thickness. But the antient strata uniformly preserve the same dimensions through their whole extent. Besides, these modern strata may be distinguished, with certainty, by the form of the stones and gravel they contain, which bear evident marks of having been rolled, smoothed, and rounded, by the motion of water. The same observation may be made with regard to those beds of turf, and corrupted vegetables, which are found in marshy grounds, immediately below the soil: They have no claim to antiquity, but have derived their existence from successive accumulations of decayed trees, and other plants. The strata of slime, or mud, which occur in many places,

places, are also recent productions, formed by stagnating waters, or the inundations of rivers. They are not so exactly horizontal, nor so uniformly inclined, as the more antient strata, produced by the regular motions of the sea. In strata formed by rivers, we meet with river, but seldom with sea-shells; and the few which occur are broken, detached, and placed without order. But, in the antient strata, there are no river-shells; the sea-shells are numerous, well preserved, and all placed in the same manner, having been transported and deposited at the same time, and by the same cause. From whence could this beautiful regularity proceed? Instead of regular strata, why do we not find the matters composing the earth huddled together without order? Why are not rocks, marbles, clays, marls, &c. scattered promiscuously, or joined by irregular or vertical strata? Why are not heavy bodies uniformly found in a lower situation than light ones? It is easy to perceive, that this uniformity of nature, this species of organization, this union of different materials by parallel strata, without regard to their weights, could only proceed from a cause equally powerful and uniform as the motions of the sea, produced by regular winds, by the tides, &c.

These causes act with superior force under the equator than in other climates; for there the tides are higher, and the winds more uniform.

form. The most extensive chains of mountains are likewise in the neighbourhood of the equator. The mountains of Africa and Peru are the highest in the world, often extending through whole continents, and stretching to great distances under the waters of the ocean. The mountains of Europe and Asia, which extend from Spain to China, are not so elevated as those of Africa and South America. According to the relations of voyagers, the mountains of the north are but small hills, when compared with the mountains of the equatorial regions. Besides, in the northern seas, there are few islands; but, in the Torrid Zone, they are innumerable. Now, as islands are only the summits of mountains, it is apparent, that there are more inequalities on the surface of the earth near the equator, than in northerly climates.

Those prodigious chains of mountains which run from west to east in the Old Continent, and from north to south in the New, must have been formed by the general motion of the tides. But the origin of the less considerable mountains and hills must be ascribed to particular motions, occasioned by winds, currents, and other irregular agitations of the sea: Their formation may, indeed, be owing to a combination of all these motions, which are capable of infinite variations; for the winds, and the situation of different islands and coasts, constantly change the natural course of the tides, and oblige them

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to run in every possible direction. It is not, therefore, surprising to see considerable eminences which have no determined direction in their courses. But, for our present purpose, it is sufficient to have shown, that mountains have not been produced by earthquakes, or other accidental causes, but that they are effects equally resulting from the general laws of nature, as well as their peculiar structure, and the situation of the materials of which they are composed.

But how has it happened, that this earth, which we and our ancestors have inhabited for ages, which, from time immemorial, has been an immense continent, dry, compact, and removed from the reach of the water, should, if formerly the bottom of an ocean, be now exalted to such a height above the waters, and so completely separated from them? Since the waters remained so long upon the earth, why have they now deserted it? What accident, what cause, could introduce a change so great? Is it possible to conceive a cause possessed of power sufficient to operate such an amazing effect?

These are difficult questions. But, as the facts are incontrovertible, the precise manner in which they have happened may remain a secret, without prejudice to the conclusions that ought to be drawn from them. A little reflection, however, will furnish us at least with plausible solutions *. We daily observe the sea

* See proofs, art. XIX.

gaining ground on certain coasts, and losing it on others. We know, that the ocean has a general and uniform motion from east to west; that it makes violent efforts against the rocks and the low grounds which encircle it; that there are whole provinces which human industry can hardly defend from the fury of the waves; and that there are instances of islands which have but lately emerged from the waters, and of regular inundations. History informs us of inundations and deluges of a more extensive nature. Should not all these circumstances convince us, that the surface of the earth has experienced very great revolutions, and that the sea may have actually given up possession of the greatest part of the ground which it formerly occupied? For example, let us suppose, that the Old and New worlds were formerly but one continent, and that, by a violent earthquake, the ancient Atalantis of Plato was sunk. What would be the consequence of such a mighty revolution? The sea would necessarily rush in from all quarters, and form what is now called the Atlantic Ocean; and vast continents, perhaps those which we now inhabit, would, of course, be left dry. This great revolution might be effected by the sudden failure of some immense cavern in the interior part of the globe, and an universal deluge would infallibly succeed. I should rather incline to think,

that

that such a revolution would not be suddenly accomplished, but that it would require a very long period. However these conjectures stand, it is certain, that such a revolution has happened, and I even believe that it happened naturally ; for, if a judgment of the future is to be formed from the past, we have only to attend carefully to what daily passes before our eyes. It is a fact, established by the repeated observation of voyagers, that the ocean has a constant motion from east to west. This motion, like the trade-winds, is not only perceived between the tropics, but through the whole temperate climates, and as near the poles as navigators have been able to approach. As a necessary consequence of this motion, the Pacific Ocean must make continual efforts against the coasts of Tartary, China, and India ; the Indian Ocean must act against the east coast of Africa ; and the Atlantic must act in a similar manner against all the eastern coasts of America. Hence the sea must have gained, and will always continue to gain, on the east, and to lose on the west. This circumstance alone would be sufficient to prove the possibility of the change of sea into land, and of land into sea. If such is the natural effect of the sea's motion from east to west, may it not reasonably be supposed, that Asia, and all the eastern continent, is the most antient country in the world ? and that Europe, and part of Africa, especially the west parts of these continents, as Britain, France, Spain, &c.

are

are countries of a more recent date? Both history and physics concur in establishing this hypothesis.

But, beside the constant motion of the sea from east to west, other causes concur in producing the effect just mentioned. There are many lands lower than the level of the sea, and are defended by a narrow isthmus of rock only, or by banks of still weaker materials. The action of the waters must gradually destroy these barriers; and, consequently, such lands must then become part of the ocean. Besides, the mountains are daily diminishing, part of them being constantly carried down to the valleys by rains. It is likewise well known, that every little brook carries earth, and other matters, from the high grounds into the rivers, by which they are at last transported to the ocean. By these means the bottom of the sea is gradually filling up, the surface of the earth is approaching to a level, and nothing but time is wanting for the sea's successively changing places with the land.

I speak not here of causes removed beyond the sphere of our knowledge, of those convulsions of nature, the slightest effort of which would be fatal to the globe. The near approach of a comet, the absence of the moon, or the introduction of a new planet into the system, &c. are suppositions upon which the imagination may rove at large. Causes of this kind will produce any effect we choose. From a single hy-

pothesis of this nature, a thousand physical romances might be composed, and their authors might dignify them with the title of *Theory of the Earth*. As an historian, I reject these vain speculations: They depend upon mere possibilities, which, if called into action, necessarily imply such a devastation in the universe, that our globe, like a fugitive particle of matter, escapes observation, and is no longer worthy of our attention. But, to give consistency to our ideas, we must take the earth as it is, examine its different parts with minuteness, and, by induction, judge of the future, from what at present exists. We ought not to be affected by causes which seldom act, and whose action is always sudden and violent. These have no place in the ordinary course of nature. But operations uniformly repeated, motions which succeed one another without interruption, are the causes which alone ought to be the foundation of our reasoning.

Some examples shall be given: We shall combine particular effects with general causes, and give a detail of facts, which will illustrate and explain the different alterations that the earth has undergone, whether by irruptions of the sea upon the land, or by the sea's retiring from lands which it formerly covered.

That irruption which gave rise to the Mediterranean * is undoubtedly the greatest †. The

* Proofs, art. XI. and XIX.
p. 209. ; Plot. Hist. Nat. &c.

† Ray's Discourses,

ocean runs with prodigious rapidity through a narrow passage between two promontories*, and then forms a vast sea, which, exclusive of the Black Sea, is about seven times larger than the kingdom of France. The motion through the Straits of Gibraltar is contrary to the motion in every other strait. The general motion of the sea is from east to west; but, in the Straits of Gibraltar, it is from west to east; an incontestible proof, that the Mediterranean Sea is not an ancient gulf, but that it has been formed by an irruption, produced by some accidental cause, such as an earthquake swallowing up the barrier, or a violent effort of the ocean, occasioned by the wind, and forcing its way through the bank between the two promontories of Gibraltar and Ceuta. This opinion is supported by the testimony of the ancients†, who inform us, that there was a time when the Mediterranean had no existence. It is likewise confirmed by natural history, and by observations upon the strata on the opposite coasts of Africa and Spain, where, as in neighbouring mountains, the beds of earth and stone are precisely the same at equal levels.

When the ocean forced this passage, it ran through the Straits with much more rapidity than at present, and instantly deluged that large tract of land which formerly joined Europe to

* Phil. Trans. abridged, vol. 2. p. 289.
Siculus, Strabo.

† Diodorus

Africa. The waters covered all the grounds which were lower than the level of the ocean ; and no part of them is now to be seen, except the tops of some of the mountains, such as part of Italy, Sicily, Malta, Corfica, Sardinia, Cyprus, Rhodes, and the islands of the Archipelago.

I have not mentioned the Black Sea as an effect of this irruption ; because the quantity of water it receives from the Danube, the Nieper, the Don, and other rivers, is more than sufficient both to form and support this sea. Besides, it runs with great rapidity through the Bosphorus into the Mediterranean *. It may even be supposed that the Black and Caspian Seas were only two large lakes, which were perhaps joined by a narrow communication, or rather by a morass, or small lake, uniting the Don and the Wolga about Tria, where these two rivers run very near each other. It is likewise probable, that these two seas, or lakes, were formerly of a much greater extent ; for the large rivers which fall into the Black and Caspian Seas must have gradually brought down a quantity of earth and sand sufficient to stop up the communication, and to form that neck of land by which these two seas are divided. We know, that large rivers, in a course of time, block up seas, and form new lands, as in the province at the mouth of the Yellow River in China ; Louisiana at the

* Phil. Transf. abridged, vol. 2. p. 289.

mouth of the Mississippi ; and the northern part of Egypt, which derived its existence * from the inundations of the Nile †. Such quantities of earth are brought down, by the rapidity of the Nile, from the interior parts of Africa, and deposited during the inundations, that you may dig fifty feet deep before you can reach the bottom of the slime and mud. Louisiana, and the province of the Yellow River, have, in the same manner, been originally formed by the slime of rivers.

Farther, the Caspian Sea is a real lake. It has no communication with any other sea, not even with the Lake Aral, which appears to have been a part of it, being only separated by a large tract of sand, in which neither river nor canal for carrying off the waters have been discovered. This sea, therefore, has no external communication with any other ; and I doubt much if there is any reason to suspect a subterraneous communication with the Black Sea, or with the Gulf of Persia. The Caspian, it is true, receives the Wolga, and several other rivers, which appear to furnish as much water as is lost by evaporation. But, independent of the difficulties attending such calculations, if it communicates with any other sea, a uniform and rapid current towards the place of communication would be an infallible consequence ; but nothing of this kind has yet been discovered. Travellers of the best

* Shaw's Travels.

† Proofs, art. XIX.

credit assure us of the contrary. We, therefore, conclude, that the Caspian Sea receives just as much water from the rivers and clouds as it loses by evaporation.

It is not improbable, that the Black Sea will, in time, be entirely divided from the Mediterranean ; and that the Bosphorus will be choked up, whenever the rivers shall have accumulated a sufficient quantity of materials to bring about that effect. It is impossible to fix the æra of this event ; but time, and the diminution of waters in rivers, in proportion as the mountains are lowered by the causes mentioned above, will one day exhibit this phænomenon to the world.

The Caspian and Black Seas should, therefore, be considered rather as lakes than as gulfs of the ocean ; because they exactly resemble other lakes which receive a number of rivers without any visible outlet, as the Dead Sea, several lakes in Africa, and elsewhere. Besides, the saltness of these two seas is not nearly equal to that of the Mediterranean or of the ocean ; and, it is an agreed point, that the navigation in the Caspian and Black Seas, on account of their numberless shoals, rocks, and banks, is so extremely hazardous, that small vessels only can be used in them with safety. This circumstance farther proves, that these seas ought not to be considered as gulfs of the ocean, but as vast collections of water amassed by large rivers.

If

If the isthmus which separates Africa from Asia were cut, it would necessarily create a great irruption of the sea upon the land. This junction was formerly projected by the Kings of Egypt, and adopted since by the Califs. I doubt whether the pretended communication between the Red Sea and Mediterranean be sufficiently established. The Red Sea is a narrow branch of the ocean: Through its whole extent, not a single river runs into it from the Egyptian side, and very few from the opposite. This sea will not, therefore, be subject to diminution, like those seas or lakes which are actually impaired by the slime and sand brought down by large rivers. The Red Sea receives all its waters directly from the ocean, and the motion of the tides in it are very discernible; of course, it must be affected by the general motions of the ocean. The Mediterranean, on the other hand, must be lower than the ocean; because the current through the Straits is exceedingly rapid. Besides, it receives the Nile, which runs parallel to the west coast of the Red Sea, and passes through the longest extent of Egypt, which is a very low country. From these circumstances, it is at least probable, that the Red Sea is higher than the Mediterranean, and, consequently, that, if the isthmus of Suez were cut, a great inundation, and a considerable augmentation of the Mediterranean, would ensue; especially if the waters were not restrained by dikes and sluices, placed

at proper distances. This precaution was probably used, if ever the ancient canal subsisted.

But, not to spend time on conjectures, which, however well founded, may perhaps appear rash, we shall give some certain and recent examples of the changes of sea into land, and of land into sea *. At Venice, the bottom of the sea is constantly rising: If the canals had not been carefully kept clean, the moats and city would, long ere now, have formed a part of the continent. The same thing may be said of most harbours, bays, and mouths of rivers. In Holland, the bottom of the sea is elevated in many places; the gulf of Zuderzee and the straits of the Texel cannot receive such large vessels as formerly. At the mouth of almost every river, we find small islands, and banks of earth and sand brought down from the higher grounds; and it is incontrovertible, that the sea is constantly dammed up, wherever great rivers empty themselves. The Rhine is lost in the sands which itself has accumulated. The Danube, the Nile, and all large rivers, after having transported great quantities of slime, sand, &c. never more arrive at the sea by a single channel; they split into branches, the intervals of which consist of the materials which they themselves have transported. Marshes are daily drained; lands, abandoned by the sea, are now plowed and sown; we navigate whole countries now covered by the

* Proofs, art. XIX.

waters; in a word, we see so many instances of land changed into water, and water into land, that we must be convinced of the continual, though slow, progress of such changes in all places. Hence the gulfs of the ocean will in time become continents; the isthmuses will be changed into straits; and the tops of the mountains will be metamorphosed into shoaly rocks in the sea.

The waters, therefore, have covered, and may still cover, every part of the earth which is now dry. Hence our astonishment at finding the productions of the sea dispersed every where, and a composition of bodies, which could not be effected by any other means than the operation of the waters, ought for ever to cease. We have already explained how the horizontal strata of the earth were formed. But those perpendicular fissures, which are equally diffused through rocks, clays, and every constituent material of the globe, remain to be considered. The perpendicular fissures are indeed placed at greater distances from each other than the horizontal; and the softer the matter, the more distant are the fissures. In marble and hard stone, the perpendicular fissures are only a few feet asunder. If the mass of rock be extensive, the distance betwixt the fissures is some fathoms: Sometimes they extend from the summit to the base of the rock, and sometimes they terminate after arriving at a horizontal fissure. They are uniformly perpendicular in the
strata

strata of all calcareous substances, as chalk, marls, marble, &c. But they are more oblique, and less regularly situated, in vitrescent bodies, brown free-stone, and rocks of flint, where they are often adorned with crystals and other minerals. In quarries of marble, or of calcareous stone, the fissures are filled with spar, gypsum, gravel, and an earthy sand, which contains a considerable portion of chalk. In marls, and every other species of earth, except sand-stone, the perpendicular fissures are either empty, or filled with such matters as have been transported thither by water.

The cause of perpendicular fissures is easily investigated. As the various materials which constitute the different strata were transported by the waters, and deposited in the form of sediments, they would at first be in a very diluted state, and would gradually harden and part with the superfluous quantity of water they contained. In the process of drying, they would naturally contract, and of course split at irregular distances. These fissures necessarily assumed a perpendicular direction; because, in this direction, the action of gravity of one particle upon another is equal to nothing; but it acts directly opposite in a horizontal situation: The diminution in bulk could have no sensible effect but in a vertical line. I say, the contraction of the parts in drying, not the contained water forcing an issue, as has been alleged, is the cause
of

of perpendicular fissures; for I have often remarked, that the sides of these fissures, through their whole extent, correspond as exactly as the two sides of a split piece of wood. Their surfaces are rude and irregular. But, if they had taken their rise from the motion of water, they would have been smooth and polished. Hence these fissures must have been produced, either suddenly or gradually, by drying and contracting, like the cracks and fissures in green wood; and the greatest part of the water the bodies contained must have evaporated through the pores. In the chapter upon minerals, we shall demonstrate, that some part of the original water still remains in stones and several other substances; and that crystals, minerals, and some other bodies, owe their existence to this water.

Perpendicular fissures vary greatly as to the extent of their openings. Some are about half an inch, or an inch, others a foot, or two feet; some extend several fathoms, and give rise to those vast precipices which so frequently occur between opposite parts of the same rocks in the Alps and other high mountains. It is plain, that the fissures, the openings of which are small, have been occasioned solely by drying. But those which extend several feet are partly owing to another cause; namely, the sinking of the foundation upon one side, while that of the other remained firm. If the base sinks but a line or two, when the height of the rock is considerable.

able an opening of several feet, or even fathoms, will be the consequence. When rocks are founded on clay or sand, they sometimes slip a little to a side; and the fissures are of course augmented by this motion. I have not hitherto mentioned those large openings, those prodigious cuts, which are to be met with in rocks and mountains: These could not be produced by any other means than the sinking of immense subterraneous caverns which were unable longer to sustain their incumbent load. But these cuts or intervals in mountains are not of the same nature with perpendicular fissures: They appear to have been ports opened by the hand of nature for the communication of nations. This seems to be the intention of all large openings in chains of mountains, and of those straits by which different parts of the ocean are connected; as the Straits of Thermopylae, of Gibraltar, &c. ; the gaps or ports in Mount Caucasus, the Cordeliers, &c. A simple separation, by the drying of the matter, could not produce this effect: Large portions of earth must have been sunk, swallowed up, or thrown down*.

These great sinkings, though occasioned by accidental and secondary causes†, are leading facts in the history of the earth, and have contributed greatly in changing the appearance of its surface. Most of them have been produced by subterraneous fires, the explosions of which

* *Propfs*, art XVII.

† *Ibid*.

give rise to earthquakes and volcano's. The force of inflamed matter, shut up in the bowels of the earth, is irresistible *. By the action of subterraneous fires, whole cities have been swallowed up, mountains, and large tracts of country, have been overturned and rendered unfit for the habitation of men. But, though this force be great, though its effects appear to be prodigious, we cannot assent to the opinions of some authors, who suppose that these subterraneous fires are only branches of an immense abyss of flame in the centre of the earth. Neither do we credit the common notion, that these fires have their seat at a great depth below the surface; for matter cannot begin to burn, or at least the inflammation cannot be supported, without air. In examining the materials which issue from volcano's, even in their most violent eruptions, it is easy to perceive that the furnace is not very deep, and that the inflamed substances are the same with those on the top of the mountain, only disfigured by calcination and the melting of the metallic particles they contain. To be convinced that the matters thrown out by volcano's come not from any considerable depth, we need only attend to the height of the mountain, and consider the immense force which would be necessary to project stones and minerals to the height of half a league; for *Ætna*,

* *Agricola de rebus quæ effluunt e terra. Phil. Trans. abrid. vol. ii. p. 391. Ray's Discourses, p. 272.*

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Hecla, and other volcano's, have at least that elevation.

Now, it is well known that fire acts equally on all sides ; it cannot, therefore, act upwards with a force sufficient to throw large stones half a league high, without an equal re-action on the base and sides. But the sides of the mountain would very soon be pierced and blown to pieces by this re-action ; because the materials of which it consists are not more dense or firm than those which are projected. How, then, can it be imagined, that the cavity, which must be considered as the tube or cannon, could possibly resist a force necessary to raise such heavy bodies to the mouth of the volcano ? Besides, suppose the cavity deeper, as the external orifice is not great, it would be impossible for so large a quantity of liquid and burning matters to issue forth at a time, without clashing against each other, and against the irregular sides of the cavity ; and, in passing through so long a space, they would be in danger of cooling and congealing. Rivers of melted sulphur and bitumen, projected from volcano's along with stones and minerals, run from the tops of the mountains into the plains. Is it natural to think, that matter so fluid, so little able to resist violent action, could be projected from a very great depth ? Every observation which can be made on this subject will tend to prove, that the fire in volcano's is not very distant from the tops of

the mountains, and never descends so low as the level of the plains *.

This account of volcano's, however, is not inconsistent with their being the cause of considerable earthquakes; neither does it contradict the communication of one volcano with another, by means of subterraneous passages †. But the depth of the furnace is the object of our present investigation; and it cannot be very distant from the mouth of the volcano. To produce an earthquake, in a plain, it is not necessary that the bottom of the volcano should be below the level of that plain, nor that there should be subterraneous cavities filled with the same burning matter under the plain. A violent explosion, with which eruptions are uniformly accompanied, may, like that of a powder-magazine, give such a concussion as to produce, by its re-action, an earthquake of considerable extent.

I mean not to say that there are no earthquakes which derive their existence from subterranean fires ‡; but that there are earthquakes produced solely by the explosion of volcano's. In confirmation of what has been said upon this subject, volcano's seldom or never appear in plains; on the contrary, their mouths, or craters, are always found on the tops of the highest mountains. If the subterraneous fire of

* Borelli de incendiis Ætææ.
vol. ii. p. 392.

† Phil. Trans. abridged,

‡ Proofs, art. XVI.

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volcano's stretched below the plains, would not new passages be opened there during violent eruptions, rather than in the tops of the mountains, where the resistance is greater? In the first eruption, would it not have been easier to pierce a plain, than a mountain of half a league in height?

It is not difficult to discover the reason why volcano's appear only in mountains. Greater quantities of minerals, sulphur, and pyrites, exist in mountains, and nearer the surface, than in plains. The mountains have likewise this farther advantage; they are more subject to the impressions of the air, and receive more rain and moisture, by which mineral substances are capable of being fermented to such a degree as to produce actual inflammation.

To conclude, it has often been observed, that, after violent eruptions, the mountains have sunk and diminished, nearly in proportion to the quantity of matter thrown out, which is another proof that volcano's are not so deep as the base of the mountains, and even that they are not much below the summit.

In many places, earthquakes have formed considerable hollows, and even some large gaps, in mountains. All other inequalities are coeval with the mountains themselves, and owe their existence to currents in the ocean; for, in every place which has not been disturbed by accidental convulsions, the strata of mountains are parallel

parallel, and their angles correspond *. It is not difficult to distinguish subterraneous caverns and excavations formed by volcano's, from those produced by water. The latter consist only of solid rocks, the sand and clay with which they were formerly filled being carried off by the water, which is the origin of caverns in hills; for those found in plains are commonly nothing but old pits and quarries, like the salt-quarries of Maestricht, the mines of Poland, &c. But natural caverns are, proper to the mountains; the summit, or higher parts, furnish them with water, which afterwards issues out to the surface wherever it can find a passage. These caverns are the sources of springs and rivers. When a large cavern of this kind is suddenly filled up by the falling of its roof, an inundation is generally the consequence †.

From these facts, it is easy to perceive how much subterraneous fires have contributed to change both the surface and internal part of the globe. This cause has power sufficient to produce very great effects. But it is difficult to conceive how any sensible alterations upon the land can be introduced by the winds ‡. Their dominion would appear to be confined to the sea. Indeed, next to the tides, nothing has such a powerful influence upon the waters; the flux and reflux proceed with an uniform pace; their

* Proofs, art. XVII. † Phil. Trans. abridged, vol. ii.
p. 322. ‡ Proofs, art. XV.

operations are always the same ; but the action of the winds is capricious and violent. They rush on with irresistible fury, and excite such impetuous commotions, that the ocean, from a smooth and tranquil plain, in an instant is furrowed with waves which emulate the height of mountains, and dash themselves in pieces against the shores. The surface of the ocean is subject to constant alterations from the winds. But ought not the surface of the land, which has so solid an appearance, ever to remain uninfluenced by a cause of this kind ? It is consonant to experience, however, that the winds raise mountains of sand in Arabia and Africa ; that they overwhelm large plains with it ; and that they frequently carry these sands many leagues into the sea, where they accumulate in such quantities as to form banks, downs, and even islands*. It is also well known, that hurricanes are the scourge of the Antilles, of Madagascar, and of other countries, where their impetuosity is so great, that they sweep away trees, plants, and animals, together with the soil which nourished them. They drive back, they annihilate, rivers, and produce new ones ; they overthrow rocks and mountains ; they scoop out holes and gulfs in the earth, and totally change the face of those unhappy countries which give birth to them. Happily, few climates are exposed to

* Bellarmin. de ascen. mentis in Deum. Varen. Geog. p. 282. Voyag. de Pyrard, tom. i. p. 470.

the violence of those dreadful agitations of the air.

But the greatest changes upon the surface of the earth are occasioned by rains, rivers, and torrents from the mountains. These derive their origin from vapours raised by the sun from the surface of the ocean, and are transported by the winds through every climate. The progress of these vapours, which are supported by the air, and transported at the pleasure of the winds, is interrupted by the tops of the mountains, where they accumulate into clouds, and fall down in the form of rain, dew, or snow. At first, these waters descended into the plains without any fixed course*; but they gradually hollowed out proper channels for themselves. By the power of gravity, they ran to the bottom of the mountains, and, penetrating or dissolving the lower grounds, they carried along with them sand and gravel, cut deep furrows in the plains, and thus opened passages to the sea, which always receives as much water by rivers as it loses by evaporation. The windings in the channels of rivers have uniformly corresponding angles on their opposite banks; and as mountains and hills, which may be regarded as the banks of the valleys by which they are separated, have likewise sinuosities with corresponding angles, this circumstance seems to demonstrate, that the valleys have been gradually formed by currents of the

* See proofs, art. X. and XVIII.

ocean, in the same manner as the channels of rivers have been produced.

The waters which run upon the surface, and support the verdure and fertility of the soil, compose not perhaps one half of the quantity that is produced by vapour. Numberless veins of water sink deep into the bowels of the earth. In some places, you are certain of obtaining water by digging; in others, none can be found. In almost all the valleys and low grounds, at a certain depth, water is uniformly to be met with. But, in all high grounds, it is impossible to extract water from the bowels of the earth. It must be collected from the heavens. There are extensive countries where no wells can be obtained: There men, and other animals, are supplied with drink from cisterns and pools. In the east, and especially in Arabia, Egypt, and Persia, wells and springs are great and valuable rarities. To supply their place, the inhabitants have been obliged to make large reservoirs to collect the water that falls from the heavens. These works, projected and executed from public necessity, constitute the most beautiful and magnificent monuments of the east. Some eastern reservoirs have more than two square leagues of superficies, and fertilize whole provinces by numberless ducts and canals let out from all sides. But, in plain countries, furnished with large rivers, it is impossible to break the surface of the earth without finding water. In camps situated in
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the neighbourhood of rivers, it often happens that every tent may have its own well, by giving a few strokes with a pick-ax.

Most of the water, so liberally diffused through low grounds, comes from the neighbouring hills and eminences. During great rains, or the sudden melting of snow, part of the water runs upon the surface; but most of it penetrates the earth and rocks, by means of small chinks and fissures. This water rises again to the surface, whenever it can find an issue; but it often drills through sands, and creeps along till it finds a bottom of clay, or hard earth, and there forms subterraneous lakes, brooks, and perhaps rivers, of which the channels are for ever buried in oblivion. Subterraneous rivers, however, must follow the general law of nature, and uniformly run from the higher to the lower ground. Their waters must of course either fall at last into the sea, or be collected in some low place, whether at the surface or in the bowels of the earth: For there are several lakes which neither receive nor give rise to any river. A still greater number receive no considerable river, but are the sources of the largest rivers on earth; as the lakes from which the river St. Lawrence issues; the lake Chiamè, from which two large rivers arise, that water the kingdoms of Assem and Pegu; the lakes of Affiniboil in America; those of Oзера in Muscovy; those that give rise to

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the Bog and the Irtis, and many others*. It is plain, that these lakes must derive their existence from the waters of superior grounds, running through subterraneous passages. Some, indeed, have affirmed, that lakes are to be met with on the tops of the highest mountains. But this is incredible; for the lakes found on the Alps, and other elevated situations, are all overtopped by higher mountains, and derive their origin from the waters which run down the sides, or are filtered through the bowels of these superior eminences, in the same manner as the lakes in valleys are supplied.

From this reasoning, the existence of subterraneous collections of water, especially under large plains, is apparent†: For mountains, hills, and heights of every kind, are exposed on all sides to the weather. The waters which fall upon their summits, and upon elevated plains, after penetrating the earth, must, from the declivity of the ground, break out at many places in the form of springs and fountains: Of course, little water will be found in the bowels of mountains. But, in plains, as the water filtrated through the earth can find no issue, it must be collected in subterraneous caverns, or dispersed in small veins, among sand and gravel. This is the origin of the water so universally diffused through low grounds. The bottom of a pit, or well, is only a small artificial basin, into which

* Proofs, art. XI.

† Proofs, art. XVIII.

the water insinuates itself from the higher grounds. At first it generally falls in by drops; but afterwards, when the passages become more open, it receives fresh supplies from greater distances, and runs in small continued veins or rills. To this circumstance it is owing, that although water may be found in any part of a plain, only a certain number of wells can be supplied. This number is in proportion to the quantity of water diffused, or rather to the extent of the higher grounds from which it comes.

To find water, it is unnecessary to dig below the level of a river. It is commonly found at smaller depths. The water of rivers seldom spreads far in the earth by filtration. Even what is found in the earth, below the level of rivers, is not derived from them; for, in rivers which have been dried up, or whose courses have been changed, no greater quantity of water is obtained by digging, than in the neighbouring ground at an equal depth. Five or six feet of earth is sufficient to contain water, and to prevent its escape: I have often remarked, that the banks of rivulets or pools have no sensible moisture at the distance of six inches from the water. It is true, the filtration is always in proportion to the penetrability of the ground. But, upon examining the stagnating pools with a sandy bottom, it is remarkable that the moisture spreads but a few inches. Neither is the extent of it great in a vegetable soil, which is

much more loose and porous than sand or hard earth. A garden-bed, though plentifully watered, communicates little or no moisture to those adjoining. I have examined level heaps of garden-earth, of six or eight feet thick, which had remained undisturbed for some years, and found that the rain-water had never reached above three or four feet deep. I have made the same observation upon earth which had lain 200 years in ridges: Below the depth of three or four feet, it was as dry as dust. Hence the spreading of water, by filtration alone, is not so extensive as has generally been imagined. Very little can descend in this way to the bowels of the earth. But water, by its own gravity, descends from the surface to the greatest depths. It sinks through natural conduits, or forces passages for itself: It follows the roots of trees, the fissures of rocks, or interstices in the earth. It divides and expands on all hands into an infinite number of small branches or rills; and uniformly descends till its progress is stopped by clay or a solid earth, where it accumulates and breaks out to the surface in form of a spring or fountain.

It would be no easy task to make an exact calculation of the quantity of subterraneous waters which have no apparent issue*. Many authors pretend that it greatly surpasses all the waters on the surface: Not to mention those who think that the interior part of the globe is en-

* Proofs, art. X, XI. and XVIII.

tirely filled with water, it is imagined by some, that there is an infinite number of rivers, rills, and lakes, in the bowels of the earth. But this opinion seems to have no proper foundation; and it is probable, that the quantity of subterraneous waters, which never appear at the surface, is very inconsiderable; for, if the number of subterraneous rivers were so great, Why do we never see any of their mouths break out, like springs, on the surface? Besides, rivers produce considerable changes on the surface of the earth; they carry off the soil; they wear away the most solid rocks, and remove every thing that opposes their passage. The same effects would result from subterraneous rivers. But no such changes have ever been discovered; nothing below the surface is displaced; the different strata every where preserve their parallel and primitive position; and it is only in very few places that subterraneous veins of water, of any consideration, have been discovered. Thus, the internal operation of water is not great; but, as it is divided into an infinity of small veins, which are often shut up by numberless obstacles, it gives rise to many substances, which are totally different, both in form and structure, from those of the primitive matter.

From what has been advanced, we may conclude, that the flux and reflux of the ocean have produced all the mountains, valleys, and other inequalities on the surface of the earth; that
currents

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currents of the sea have scooped out the valleys, elevated the hills, and bestowed on them their corresponding directions; that the same waters of the ocean, by transporting and depositing earth, &c. have given rise to the parallel strata; that the waters from the heavens gradually destroy the effects of the sea, by continually diminishing the height of the mountains, filling up the valleys, and choaking the mouths of rivers; and, by reducing every thing to its former level, they will, in time, restore the earth to the sea, which, by its natural operations, will again create new continents, interspersed with mountains and valleys, every way similar to those which we now inhabit.

P R O O F S

OF THE

THEORY OF THE EARTH.

A R T I C L E I.

Of the Formation of Planets.

AS natural history is our proper subject, we would willingly dispense with astronomical observations. But, as the earth is so nearly related to the heavenly bodies, and, as observations of this kind illustrate more fully those doctrines we have already advanced, it is necessary to give some general ideas concerning the formation, motion, and figure, of the earth, and other planets.

The earth is a globe of about 3000 leagues in diameter; it is situated 30 million of leagues from the sun, round which it revolves in 365 days. This annual revolution is the effect of two forces; the one may be considered as an impulse from right to left, or from left to right;

the other as an attraction from above downwards, or from below upwards, to a common centre. The direction and quantity of these forces are combined, and so nicely adjusted, that they produce a uniform motion in an ellipse approaching to a circle. Like the other planets, the earth is opaque, throws out a shadow, and reflects the rays of the sun, about which it revolves in a time proportioned to its relative distance and density. It likewise revolves about its own axis in 24 hours; and its axis is inclined to the plane of its orbit $66\frac{1}{2}$ degrees. Its figure is that of a spheroid, the two axes of which differ from each other about an 165th part; and it revolves round the shortest axis.

These are the principal phenomena of the earth, the results of discoveries made by means of geometry, astronomy, and navigation. It is unnecessary here to enumerate the proofs and observations by which these facts have been established. We shall confine our remarks to such objects as are still doubtful; and shall therefore proceed to give our ideas concerning the formation of planets, and the changes they have undergone, previous to their arriving at the state in which we now perceive them. To the many systems and hypotheses which have been framed concerning the formation of the earth, and the different states it has passed through, we may be allowed to add our own conjectures, especially as we are determined to support them with a superior

superior degree of probability ; and we are the more encouraged to deliver our notions on this subject, because we hope to enable the reader to distinguish between an hypothesis which consists only of possibilities, and a theory supported by facts ; between a system, such as we are about to give, of the formation and primitive state of the earth, and a physical history of its real condition, which has been delivered in the preceding discourse.

Galileo traced the laws of falling bodies ; and Kepler observed, that the areas which the principal planets describe in moving round the sun, and those of the satellites round their principal planets, were proportioned to the periods of their revolutions, and that these periods were as the square roots of the cubes of their distances from the sun, or from the principal planets. Newton discovered that the power of gravity extended to the moon, and retained it in its orbit ; that the force of gravity diminished in exact proportion to the squares of the distances, and, consequently, that the moon is attracted by the earth ; that the earth, and all planets, are attracted by the sun ; and, in general, that all bodies which revolve about a centre, and describe areas proportioned to the periods of their revolution, are attracted by that luminary. Gravity, therefore, is a general law of nature. The planets, comets, the sun, the earth, are all subject to its laws ; and it is the source of that harmony

mony which prevails in the universe. Nothing in physics is better established than the existence of this power in every material body. Repeated experience has confirmed the effects of its influence, and the labour and ingenuity of geometers have determined its quantity and relations.

This general law being once discovered, the effects of it would be easily explained, if the action of those bodies which produce them were not too complicated. A slight view of the solar system will convince us of the difficulties which attend this subject. The principal planets are attracted by the sun, the sun by the planets, the satellites by the principal planets, and each planet attracts all the others, and is attracted by them. All these actions and re-actions vary according to the quantities of matter and the distances, and give rise to great inequalities, and even irregularities. How are so many relations to be combined and estimated? Among such a number of objects, how is it possible to trace any individual? These difficulties, however, have been surmounted; the reasonings of theory have been confirmed by calculation; every observation has produced a new demonstration; and the systematic order of the universe is now laid open to every man who is able to distinguish truth from error.

The force of impulsion, or what is commonly called the centrifugal force, is still unknown; but

but it affects not the general theory. It is evident, that, as the attractive force continually draws all the planets towards the sun, they would fall in a perpendicular line into that luminary, if they were not kept at a distance by some other power, forcing them to move in a straight line. If, again, this impulsive force were not counteracted by that of attraction, all the planets would fly off in the tangents of their respective orbits. This progressive or impulsive force was unquestionably at first communicated to the planets by the Supreme Being. But, in physical subjects, we ought, as much as possible, to avoid having recourse to supernatural causes; and, I imagine, a probable reason may be assigned for the impulsive force of the planets, which will be agreeable to the laws of mechanics, and not more surprising than many revolutions that must have happened in the universe.

The sphere of the sun's attraction is not limited by the orbits of the planets, but extends to an indefinite distance, always decreasing according as the squares of the augmented distances. The comets, it is evident, which escape our sight in the heavenly regions, are, like the planets, subject to the attraction of the sun, and by it their motions are regulated. All these bodies, the directions of which are so various, move round the sun, and describe areas proportioned to their periods, the planets in ellipses, more or less circular, and the comets, in narrow ellipses of vast extent.

extent. The motions, therefore, both of planets and comets, are regulated by impulsive and attractive forces continually acting upon them, and obliging them to describe curves. But it is worthy of remark, that comets run through the system in all directions; that the inclinations of the planes of their orbits are so very different, that though, like the planets, they be subject to the law of attraction, they have nothing in common with regard to their progressive or impulsive motions, but appear, in this respect, to be absolutely independent of each other. The planets, on the contrary, move round the sun in the same direction, and nearly in the same plane, the greatest inclination of their planes not exceeding $7\frac{1}{2}$ degrees. This similarity in the position and motion of the planets indicates, that their impulsive and centrifugal forces must have originated from one common cause.

May we not conjecture, that a comet falling into the body of the sun might drive off some parts from its surface, and communicate to them a violent impulsive force, which they still retain? This conjecture appears to be as well founded as that of Mr Leibnitz, which supposed the earth and planets to have formerly been suns; and his system, of which an abridgment will be given in Art. V. would have been more comprehensive, and more consonant to probability, if it had embraced the above idea. We agree with him, that this effect was produced at the

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the time when God is said by Moses to have separated the light from the darkness; for, according to Leibnitz, the light was separated from the darkness when the planets were extinguished. But, on our supposition, there was a real physical separation*, because the opaque bodies of the planets were detached from the luminous matter of which the sun is composed*.

This notion concerning the cause of the centrifugal force of the planets will appear to be less exceptionable, after we have collected the analogies, and estimated the degrees of probability by which it may be supported. We shall first mention, that the motion of the planets have one common direction, namely, from west to east. By the doctrine of chances, it is easy to demonstrate, that this circumstance makes it as 64 to 1, that the planets could not at all move in the same direction, if their centrifugal forces had not proceeded from the same cause.

This probability will be greatly augmented, if we consider the similarity in the inclinations of the planes of their orbits, which exceed not $7\frac{1}{2}$ degrees; for, by calculations, it has been discovered, that it is 24 to 1 against any two planets being found, at the same time, in the most distant parts of their orbits; and, consequently, 24^5 , or 7692624 to 1, that this effect could not

* If the Count de Buffon had known, that the nucleus of the sun was a solid and opaque matter, a discovery lately made by the ingenious Dr. Wilson of Glasgow, his hypothesis would have laboured under fewer difficulties.

66 OF THE FORMATION

be produced by accident; or, what amounts to the same, there is this great degree of probability, that the planets have been impressed with one common moving force, from which they have derived this singular position. But nothing could bestow this common centrifugal motion, except the force and direction of the bodies by which it was originally communicated. We may, therefore, conclude, that all the planets have probably received their centrifugal motion by one single stroke. Having established this degree of probability, which almost amounts to a certainty, I next inquire what moving bodies could produce this effect; and I can find nothing but comets capable of communicating motion to such vast masses.

Upon examining the course of comets, it is easy to believe that some of them must occasionally fall into the sun. The comet 1680 approached so near, that at its perihelion, it was not more distant from the sun than a sixteenth part of his diameter; and, if it returns, which is extremely probable, in the year 2255, it may then fall into the sun. This event must depend upon the accidents it meets with in its course, and the retardations it suffers in passing through the sun's atmosphere*.

We may, therefore, presume, with the great Newton, that comets sometimes fall into the sun. But they may fall in different directions.

* See Newt. edit. 3. p. 525.

If they fall perpendicularly, or in a direction not very oblique, they will remain in the body of the sun, serve the purposes of fuel, and, by their impulse, remove the sun from his place, in proportion to the quantity of matter they contain*. But, if a comet falls in a very oblique direction, which will most frequently happen, it will only graze the surface, or penetrate to no great depth. In this case, it may force its way past the sun, detach certain portions of his body, to which it will communicate a common impulsive motion; and these portions pushed off from the sun, and even the comet itself, may turn planets, which will revolve round this luminary in the same direction, and nearly in the same plane. A calculation, perhaps, might be made of the quantity of matter, velocity, and direction, a comet ought to have, in order to force from the sun masses equal to those which compose the six planets and their satellites. But it is sufficient here to observe, that the whole planets, with their satellites, make not a 650th part of the sun's mass†; for although the density of Saturn and Jupiter be less than that of the sun, and though the earth be four times, and the moon near five times, more dense than the sun; yet they are only atoms when compared to his immense volume.

* Quær. Would not such an event, by augmenting the sun's quantity of matter, and, consequently, his attractive power, produce other changes in the solar system? † See Newt. p. 405.

It must be acknowledged, that, although a 650th part of a whole may seem inconsiderable, it would require a very large comet to detach this part from the sun. But, if we consider the prodigious rapidity of comets in their perihelion; the near approach they make to the sun; the density and strong cohesion of parts necessary to sustain, without destruction, the inconceivable heat they undergo; and the solid and brilliant nucleus which shines through their dark atmospheres; it cannot be doubted that comets are composed of matters extremely dense and solid; that they contain, in small limits, a great quantity of matter; and, consequently, that a comet of no enormous size may remove the sun from his place, and give a projectile motion to a mass of matter equal to the 650th part of his body. This remark corresponds with what we know concerning the respective densities of the planets, which always decrease in proportion to their distances from the sun, having less force of heat to resist. Accordingly, Saturn is less dense than Jupiter, and Jupiter much less than the earth. Thus, if the density of the planets, as Newton alleges, be in proportion to the quantity of heat they support, Mercury will be seven times denser than the earth, and 28 times denser than the sun, and the comet 1680, 28,000 times more dense than the earth, or 112,000 times denser than the sun. Now, supposing the quantity of matter in this comet to be equal to a
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ninth part of the sun, or allowing it to be only 100th part of the bulk of the earth, its quantity of matter would still be equal to a 900th part of the sun: Hence a body of this kind, which would be but a small comet, might push off from the sun a 900th or a 650th part, especially when the amazing rapidity of comets, in their perihelion, is taken into the calculation.

The correspondence between the density of the whole planets, and that of the sun, deserves also to be noticed. Upon, and near the surface of the earth, there are substances 1400 or 1500 times denser than others; the densities of air and gold are nearly in this proportion. But the interior parts of the earth and planets are more uniform, and differ little with regard to density; and the correspondence in the density of the planets and that of the sun is so great, that, out of 650 parts, which comprehend the whole density of the planets, there are more than 640 nearly of the same density with the solar matter; and there are only ten of those 650 which are of a superior density; for the density of Saturn and Jupiter is nearly the same with that of the sun; and the quantity of matter in those two planets is at least 64 times greater than what is contained in the four inferior planets, Mars, the Earth, Venus, and Mercury. We may, therefore, conclude, that, in general, the matter of the planets is very nearly of the same

kind with the solar matter, and, of course, that the former may have been separated from the latter.

To this theory it may be objected, that, if the planets had been driven off from the sun by a comet, in place of describing circles round him, they must, according to the law of projectiles, have returned to the same place from whence they had been forced? and, therefore, that the projectile force of the planets cannot be attributed to the impulse of a comet.

I reply, that the planets issued not from the sun in the form of globes, but in the form of torrents, the motion of whose anterior particles must have been accelerated by those behind, and the attraction of the anterior particles would also accelerate the motion of the posterior; and that this acceleration, produced by one or both of these causes, might be such as would necessarily change the original motion arising from the impulse of the comet, and that, from this cause, might result a motion similar to what takes place in the planets, especially when it is considered, that the shock of the comet removes the sun out of its former station. This reasoning may be illustrated by an example. Suppose a musket-ball discharged from the top of a mountain, and that the force of the powder was sufficient to push it beyond a semidiameter of the earth, it is certain that this ball would revolve round
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the earth, and return at every revolution to the place from whence it had been discharged. But, instead of a musket-ball, if a rocket were employed, the continued action of the fire would greatly accelerate the original impulsive motion. This rocket would by no means return to the same point, like the ball; but, *cæteris paribus*, would describe an orbit, the perigee of which would be more or less distant from the earth in proportion to the greatness of the change produced in its direction by the accelerating force of the fire. In the same manner, if the original projectile force impressed by the comet on the torrent of solar matter was accelerated, it is probable, that the planets formed by this torrent acquired their present circular or elliptical movements around the sun.

The appearances exhibited in great eruptions from volcano's may give some idea of this acceleration of motion. When Vesuvius begins to groan and throw out inflamed matter, it has been often remarked, that the motion of the cloud first ejected is slower than the succeeding ones, and that they go on increasing in celerity, till at last sulphur, lava, melted metal, and huge stones are thrown up; and that, though these observe nearly the same direction, they alter considerably that of the first cloud, and elevate it to a greater height than it would otherwise have reached.

The objection will be still farther obviated, if it is considered, that the impulse of the comet must, in some degree, have communicated a motion to the sun, and removed it from its former situation; and that, although this motion may now be so small as to escape the notice of astronomers, it may still, however, exist, and make the sun describe a curve round the centre of gravity of the system. If this be allowed, as I presume it will, the planets, instead of returning to the sun's body, would describe orbits, the perihelions of which would be as distant from the sun as the space that he presently occupies is distant from his original station.

It may be farther objected, that, if motion be accelerated in the same direction, no change in the perihelion could take place. But is it credible, that no change of direction can happen in a torrent whose particles succeed each other? On the contrary, it is extremely probable, that a change was actually produced sufficient to make the planets move in their present orbits.

It may still be objected, that, if the situation of the sun had been changed by the shock of a comet, it would move uniformly; and, of course, this motion being common to the whole system, no alteration would be effected. But, previous to the shock, might not the sun move round the centre of the cometary system; and might
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not this primary motion be augmented or diminished by the stroke of the comet? Is not this sufficient to account for the actual motion of the planets?

If none of these suppositions be admitted, may it not be presumed, that the elasticity of the sun might elevate the torrent above his surface, in place of pushing it directly forward? This circumstance alone would be sufficient to remove the perihelion, and endow the planets with their present movements. Neither is this supposition destitute of foundation: The solar matter may be exceedingly elastic; since light, the only part of it we are acquainted with, seems, by its effects, to be perfectly elastic. I acknowledge that I cannot determine which of the causes above assigned has actually produced an alteration in the projectile force of the planets; but they at least show that such a change is not only possible, but probable, which is enough for my present purpose.

Without farther insisting on the objections which may be made against my hypothesis, or the analogical proofs that might be brought in support of it, I shall prosecute my subject, and draw the proper conclusions. Let us first examine what might happen to the planets, and particularly to the earth, when they were impressed with their projectile forces, and what was their state after their separation from the body of the sun.

fun. A projectile motion having been communicated, by the stroke of a comet, to a quantity of matter equal to a 650th part of the sun's mass, the light particles would separate from the dense, and, by their mutual attractions, form globes of different solidities. Saturn being composed of the largest and lightest parts, would be removed to the greatest distance from the sun; Jupiter, being denser than Saturn, would have a nearer station; and so of the rest. The largest and least solid planets are most distant, because they received a greater projectile force than the smaller and denser; for the projectile force being proportioned to the surface to which it is applied, the same stroke would make the larger and lighter parts of the solar matter move with more rapidity than the smaller and heavier. The parts, therefore, which differed in density, would separate from each other in such a manner, that, if the density of the solar matter be equal to 100, that of Saturn will be equal to 67, of Jupiter, = $94\frac{1}{2}$, of Mars, = 200, of the Earth, = 400, of Venus, = 800, of Mercury, = 2800. But, as the attractive force acts not in proportion to the surface, but to the quantity of matter, it would retard the progress of the more dense parts of the solar matter; and it is for this reason that we find the most dense planets nearest the sun, and which move round him with more rapidity than those that are more distant, and less dense.

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The density and projectile motion of Saturn and Jupiter, the two largest planets in the system, have the most exact proportion. The density of Saturn is to that of Jupiter as 67 to $94\frac{1}{2}$, and their velocities are nearly as $88\frac{2}{3}$ to $120\frac{1}{3}$, or as 67 to $90\frac{1}{6}$. How rarely do pure conjectures correspond so exactly to the phenomena of nature? It is true, according to this relation between the celerity and density of the planets, the density of the earth ought not to exceed $206\frac{7}{8}$, instead of 400 , which is its real density; hence it may be supposed, that the earth has now double its original density. With regard to the other planets, Mars, Venus, and Mercury, as their densities are only conjectural, we know not whether this circumstance would confirm or weaken our hypothesis. Newton says, that the densities of the planets are proportioned to the degrees of heat they are exposed to; and it is in consequence of this idea that we have mentioned Mars as being one time less dense than the earth, Venus one time, Mercury seven times, and the comet 1680, 28,000 times denser than the earth. But, if we attend to Saturn and Jupiter, the two principal planets, we will find, that this supposed proportion between the densities of the planets, and the heat they sustain, is not well founded: For, according to this hypothesis, the density of Saturn would be as $4\frac{7}{8}$, and that of Jupiter as $14\frac{1}{2}$, instead of the proportions of 67 and $94\frac{1}{2}$; differences so great as
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to destroy the principles upon which they are founded. Thus, notwithstanding the regard due to the conjectures of Newton, I cannot refrain from thinking that the densities of the planets have a nearer relation to their celerities than to the degrees of heat to which they are exposed. This, indeed, is only a final cause; but the other is a physical relation, the exactness of which is remarkable in Saturn and Jupiter. It is certain, however, that the density of the earth, instead of being $206\frac{2}{3}$, is 400; and, consequently, the earth must have suffered a condensation in the proportion of $206\frac{2}{3}$ to 400.

But have the condensations of the planets no relation to the quantity of solar heat they sustain? In that case, Saturn, which is at the greatest distance from the sun, would have suffered little or no condensation; and Jupiter would be condensed from $90\frac{1}{6}$ to $94\frac{1}{2}$. Now, the sun's heat in Jupiter being to his heat in the earth as $14\frac{1}{2}$ to 400, their condensation ought to be in the same proportion. Thus, if Jupiter be condensed as $90\frac{1}{6}$ to $94\frac{1}{2}$, the earth, if it had been in the orbit of Jupiter, would have been condensed from $206\frac{2}{3}$ to $215\frac{29}{33}$; but the earth being much nearer the sun, and receiving heat, in proportion to that of Jupiter, as 400 to $14\frac{1}{2}$, the quantity of condensation it would have undergone in the orbit of Jupiter must be multiplied by the proportion of 400 to $14\frac{1}{2}$, which will give nearly 234 $\frac{1}{2}$ for the condensation

tion the earth must have received. The density of the earth was $206\frac{7}{8}$; by adding its acquired condensation, its actual density will be $400\frac{1}{2}$, which is nearly the same with 400, its real density determined by the moon's parallax. With regard to the other planets, I pretend not to give exact proportions, but only approximations, tending to shew, that their densities have a strong connection with the celerity of their motions in their respective orbits.

The comet, by falling obliquely on the sun, as mentioned above, must have forced off from his surface a quantity of matter equal to a 650th part of his body: This matter, being in a liquid state, would at first form a torrent, of which the largest and rarest parts would fly to the greatest distances; the smaller and more dense, having received only an equal impulse, would remain nearer the sun; his power of attraction would operate upon all the parts detached from his body, and make them circulate round him; and, at the same time, the mutual attraction of the particles of matter would cause all the detached parts to assume the form of globes, at different distances from the sun, the nearer moving with greater rapidity in their orbits than the more remote.

But it may be objected, that, if the planets had been detached from the sun, they must have been burning and luminous, not cold and opaque bodies; nothing can have less resemblance

semblance to a globe of fire than a globe composed of earth and water ; and, by comparison, the matter of the earth is totally different from that of the sun.

It may be replied to this objection, that the matter changed its form after its separation, and that the fire, or light, was extinguished by the projectile motion communicated by the stroke. Besides, may it not be supposed, that the sun, or a burning star, moving with a rapidity equal to that of the planets, would soon be extinguished ; and that this may be the reason why all the luminous, or burning stars, are fixed, and without motion ; and why those called new stars, which have probably changed their stations, are frequently extinguished and disappear ? To confirm this remark, comets, when in their perihelia, ought to be inflamed even to their centre ; but they never become luminous stars ; they only emit a burning vapour, a considerable portion of which they leave behind them in their course.

In a medium which has little resistance, I acknowledge, that fire may subsist, although the burning body be moved with great rapidity. It must likewise be acknowledged, that what I have said applies only to those stars which disappear for ever, not to those that appear and disappear at stated intervals, without changing their situations in the heavens. Of these Maupertuis, in his discourse on the figure of the stars, has given a most satisfactory account. But those
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which have appeared, and then vanished for ever, must unquestionably have been extinguished either by the quickness of their motion, or some other cause. There is not a single example of a luminous star revolving round another; and not one of the sixteen planets which revolve round the sun have any light in themselves.

Farther, fire, in small masses, cannot subsist so long as in large ones. The planets would burn a considerable time after they issued from the sun; but, at length, would extinguish for want of combustible matter. For the same reason, the sun itself will be extinguished; but at a period as much beyond that which extinguished the planets, as the quantity of matter in the sun exceeds that of the planets. However this may be, the separation of the planets from the sun, by the shock of a comet, appears sufficient to account for their extinction.

The earth and planets, when they issued from the sun, were totally composed of liquid fire; in which state they would continue no longer than the violence of the heat that kept them in fusion. But this heat would gradually decay from the moment they left the sun. During their fluid state, they necessarily assumed circular figures; and their diurnal motion would elevate their equators, and flatten their poles. I agree with M. Leibnitz *, that this figure corre-

* Vid. Ast. Brud. Lips. an. 1692.

sponds so exactly with the laws of hydrostatics, that the earth and planets must necessarily have been once in a state of fluidity occasioned by fire; and, consequently, that the interior parts of the earth must be composed of vitrified matter, of which sand, free-stone, granite, and perhaps clay, are fragments, or scorixæ.

It is therefore extremely probable, that the planets were originally parts of the sun separated by a stroke which communicated to them a projectile motion; and that their different distances proceeded solely from the difference of their densities. To complete this theory, it only remains to account for the diurnal motion of the planets, and the origin of their satellites; which, instead of adding fresh difficulties, will tend greatly to confirm my hypothesis: For rotation, or what is called diurnal motion, entirely depends on the obliquity of the stroke; an oblique impulse on the surface of a body necessarily gives it a rotatory motion. If the body which receives the impulse be homogeneous, the rotatory motion will always be equal and uniform; but it will be unequal, if the body consist of heterogeneous parts, or of parts different in density. Hence we may conclude, that the matter of each planet is homogeneous, because the diurnal motion of each is uniformly performed in the same time; and this circumstance is an additional proof, that portions of different densities were originally separated from the sun.

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But the obliquity of the stroke might be so great as to throw off small quantities of matter from the principal planet, which would necessarily move in the same direction. These parts, by mutual attraction, would reunite, according to their densities, at different distances from the planet, follow its course round the sun, and at the same time revolve about the body of the planet, nearly in the plane of its orbit. It is easy to perceive that the portions we mean are the satellites: Thus the formation, position, and motion, of the satellites correspond, in the most perfect manner, with our theory; for they all move in the same direction, and in concentric circles round their principal planets, and nearly in the plane of their orbits. All these common effects, depending on an impulsive force, must have proceeded from a common cause, which was a projectile force communicated to them by the same oblique stroke. This account of the motion and formation of the satellites will be strongly supported, if the other circumstances and phenomena attending them be duly weighed. Those planets which are furnished with satellites move quickest round their axes. The revolution of the earth is quicker than that of Mars, in the proportion nearly of 24 to 15; the earth has a satellite, and Mars has none; Jupiter, whose diurnal motion is 500 or 600 times more rapid than that of the earth, has four satellites; and it is extremely probable, that Saturn, who

has five satellites and a ring, revolves much more quickly than Jupiter.

We may even conjecture, with some probability, that the plane of the equator of Saturn's ring is nearly the same with that of the planet ; for, supposing, according to the preceding theory, the obliquity of the impulse which put Saturn in motion to have been very great, his diurnal motion would at first be in proportion to the excess of the centrifugal force above that of gravity, and, of course, a considerable quantity of matter would be thrown off from his equatorial regions, and necessarily assume the figure of a ring, the plane of which would be nearly the same with that of his own equator. This quantity of matter, detached from the equatorial regions of Saturn, must have flattened the equator of that planet ; which is the reason why, notwithstanding the rapidity with which we have supposed him to revolve round his axis, the diameters of Saturn are not so unequal as those of Jupiter, which differ from each other more than an eleventh part.

Though this theory of the formation of the planets and their satellites appears to be extremely probable ; yet, as every man has his own standard of estimating probabilities of this nature, and as this standard varies according to the different capacities of combining analogies more or less remote, I pretend not to convince those who are unwilling to believe. I have offered these

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ideas to the public, not only because I thought them rational, and calculated to unravel a subject upon which, however important, nothing has hitherto been written ; but because the impulsive motion of the planets gives rise to numberless phænomena in the universe, which admit not of an explanation by gravity alone. To those who may be disposed to deny the possibility of my theory, I would propose the following queries :

1. Is it not natural to imagine, that a moving body has received its motion from the impulse of some other body ?

2. When several bodies move in the same direction, is it not exceedingly probable, that they received this direction from a single stroke, or, at least, from strokes every way similar ?

3. When several bodies in motion have not only the same direction, but are placed in the same plane, is it not more natural to think that they received this direction and position from one impulse than from many ?

4. Is it not probable, that a body put in motion by impulse, should receive it in an oblique direction ; and consequently that it should be forced to move round its axis with a rapidity proportioned to the obliquity of the stroke ? If these queries be not unreasonable, the theory of which we have given a sketch will no longer have the appearance of absurdity.

Let us now proceed to a more interesting object ; let us examine the figure of the earth upon which so many inquiries and observations have been made. As it appears, from the equality of the earth's diurnal motion, and the uniformity in the inclination of its axis, that it is composed of homogeneous parts which mutually attract each other in proportion to their quantities of matter ; if its impulsive motion had been communicated in a direction perpendicular to its surface, it would necessarily have assumed the figure of a perfect sphere : But, having been struck obliquely, it moved round its axis at the instant it received its figure ; and, from the combination of the projectile force and that of attraction, there resulted a spheroid figure, more elevated at the equator than at the poles ; because the centrifugal force, arising from the diurnal rotation of the earth, must diminish the action of gravity, or that power which makes all the parts tend to the centre. Thus the earth, being composed of homogeneous parts, and having been endowed with a rotatory motion, must necessarily have assumed a spheroidal figure, the two axes of which differ from each other by a 230th part. To show that this is the real figure of the earth, we need not have recourse to hypotheses ; it is capable of the clearest demonstration. The laws of gravitation are well known : That bodies attract each other
directly

directly as their quantities of matter, and inversely as the squares of their distances, admits not of a doubt. It can as little be doubted, that the total action of any body is composed of all the particular actions of its parts.

The parts of bodies are all mutually attracted in the above proportion; and all these attractions, when the body has no rotation, necessarily produce a sphere, and a spheroid, when the body is endowed with a rotatory motion. This spheroid is more or less flattened at the poles in proportion to the quickness of the diurnal motion; and the earth, in consequence of the celerity of its rotation, and the mutual attraction of its parts, has assumed the figure of a spheroid, of which the two axes are to one another as 229 to 230.

Thus the earth, at the time of its formation, from the original constitution and homogeneity of its parts, and independent of every hypothesis derived from the direction of gravity, took the figure of a spheroid; and, from the known laws of mechanics, its equatorial diameter was necessarily elevated about six leagues and a half more than its poles.

I shall dwell the longer on this article, because there are some geometers, who, from a system of philosophy they have adopted, and from a supposed direction of gravity, still imagine that the figure of the earth depends upon theory. The first thing to be demonstrated is

the mutual attraction of the parts of matter ; and the second, the homogeneity of the terrestrial globe. When these two facts are clearly proved, there will be no occasion to have recourse to any theory derived from the direction of gravity ; because the earth's figure, in this case, must necessarily be as Newton determined it ; and all the other figures assigned to it, in consequence of vortexes, and other hypotheses, can have no existence.

It will not be doubted,, even by the most incredulous, that the planets are retained in their orbits by the power of gravity. The satellites of Saturn gravitate towards that planet ; those of Jupiter towards Jupiter ; the moon gravitates towards the earth ; and Saturn, Jupiter, Mars, the Earth, Venus, and Mercury, gravitate towards the sun. In the same manner, Saturn, Jupiter, and the Earth, gravitate towards their respective satellites, and the sun gravitates towards the whole planets. Gravitation is therefore a general law, by which the whole planetary system is mutually affected ; for action cannot exist without re-action. This mutual attraction of the planets is the law which regulates all their motions ; and its existence is demonstrated by its effects. When Saturn and Jupiter are in conjunction, their mutual attraction produces an irregularity in their motion round the sun. The earth and the moon, also, mutually attract each other ; but the irregularities in the moon's motion

tion proceed principally from the attraction of the sun ; and hence the sun, the earth, and the moon, mutually act upon each other. Now, the reciprocal attraction of the planets, when the distances are equal, is proportioned to their quantities of matter ; and the same power of gravity, which makes heavy bodies fall to the earth, and which extends as far as the moon, is likewise in proportion to the quantity of matter : The total gravity of a planet, therefore, is composed of the gravity of all its parts : Hence all the parts of matter, whether in the earth or planets, mutually attract each other ; and, of course, the rotation of the earth round its axis must necessarily have bestowed on it the figure of a spheroid, the axes of which are as 229 to 230. But the direction of gravity must be perpendicular to the earth's surface ; and, consequently, unless the general and mutual attraction of the parts of matter be denied, no hypothesis derived from the direction of gravity can have any solid foundation. But this mutual attraction, as we have seen, is demonstrated by actual observation ; and the experiments made by pendulums prove its universal extension. No hypothesis, therefore, founded on the direction of gravity, can be admitted, without contradicting both reason and experience.

Let us now examine whether the parts composing the terrestrial globe be homogeneous. I acknowledge, that, if the globe be supposed to

consist of parts differing in density, the direction of gravity would be different from that we have assigned, and that the earth's figure would vary according to the different suppositions which might be made concerning the direction of gravity. But, why make suppositions of this kind? Why, for example, do we suppose the parts near the centre to be more dense than those more distant from it? Are not all the particles which compose the globe united by their mutual attraction? Every particle, therefore, is a centre; and there is no reason to believe that the parts which surround the centre are denser than those which surround any other point. Besides, if any considerable part of the earth were more dense than another, the axis of rotation would approach nearer that part, and create an inequality in the diurnal revolution of the globe: It would produce an inequality in the apparent motion of the fixed stars; they would appear to move more quickly or slowly in the zenith or horizon, according as we happened to be situated on the heavy or light parts of the earth; and the axis of the globe, not passing through its centre of gravity, would make a perceptible change in its position. But nothing of this kind ever takes place. On the contrary, the diurnal revolution of the earth is equal and uniform. At every point of the earth's surface, the stars appear to move with the same quickness; and, if there be any nutation in its axis, it is too inconsiderable to

to attract observation. Hence it may be concluded, that all the parts of the globe are at least nearly homogeneous.

If the earth were hollow, the crust of which, for example, exceeded not three leagues in thickness, it would give rise to the following phenomena. 1. The mountains would bear so great a proportion to the total thickness of the crust, that vast irregularities in the earth's motion would be occasioned by the attraction of the moon and of the sun: When the moon was in the meridian of the more elevated parts, as the Cordeliers, her attraction upon the whole globe would be much greater than when she was in the meridian of the lower parts. 2. The comparative attraction of the mountains would be greatly increased; and the experiments made on Mount Chimboraco, in Peru, would have given more degrees in the deviation of the plumb-line than they actually gave seconds. 3. The weight of bodies would be greater on the tops of mountains than in the plains; and men would find themselves more weighty, and would walk with more difficulty, in high than in low grounds. These observations, and many others which might be made, should convince us, that the interior parts of the earth are not hollow, but that they are composed of matter of a considerable density.

If, on the other hand, the earth, at the depth of two or three leagues, consisted of matter
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much denser than that we are acquainted with, upon descending even into ordinary pits, we should find ourselves considerably heavier; and the motion of pendulums would there be more accelerated than they actually are when brought down from a hill to a plain. Hence we may presume that the interior parts of the earth consist of matter nearly similar to that on its surface. Of this, we will be still farther convinced, if we consider that the earth, at the time of its original formation, when it assumed its present spheroidal figure, was in a state of fusion, and, consequently, that all its parts were homogeneous, and nearly of equal density. The matter on the surface, though originally the same with that of the interior parts, has, in the revolutions of time, undergone many changes from external causes; and to these are to be ascribed the production of materials so different in their densities. But it ought to be remarked, that the densest bodies, as gold, and other metals, are most rarely to be met with; and, consequently, that the greatest quantity of materials at the surface, have suffered little alteration with regard to density. The most common materials, indeed, as sand and clay, differ so little in density, that we may conjecture, with much probability, the internal parts of the earth to consist of a vitrified matter, the density of which is nearly equal to that of sand; and, consequently,
that

that the whole globe may be considered as one homogeneous mass.

But, it may be said, that, though the earth were composed of concentric beds, of different densities, the equality of its diurnal motion, and the uniform inclination of its axis, would remain equally undisturbed, as upon the supposition of its consisting wholly of homogeneous matter. This I allow; but I demand, at the same time, whether there be any reason for believing that these beds of different densities really exist? Whether this method of solving difficulties be not an attempt to adjust the works of nature to our own imaginations? And whether suppositions, neither founded on observation nor analogy, ought to find admittance into physical reasoning?

Hence, it is apparent, that the earth received its spheroidal figure in consequence of its diurnal motion, and the mutual attraction of its parts; that this figure necessarily resulted from the globe's being in a liquid state; that, according to the laws of gravity and of a centrifugal force, it could not possibly assume any other figure; that, at the moment of its formation, the difference between its two diameters was, as at present, equal to a 230th part; and, of course, that all other hypotheses which make this difference greater or less, are mere fictions, and deserve no attention,

Perhaps

Perhaps it may be objected, that, if this theory be well founded, and if the proportion of the axes of the two diameters be as 229 to 230, how came the mathematicians sent to Lapland and Peru to concur in making it as 174 to 175? Why should such a difference subsist between practice and theory? And, is it not more reasonable to give the preference to actual measurement, especially when executed by the ablest mathematicians in Europe*, and furnished with all the necessary apparatus?

To this I reply, that I mean not to combat the observations made at the equator, and near the pole; that I doubt not of their exactness; and that the earth may actually be elevated a 175th part more at the equator than at the poles. Still, however, I maintain my theory; and I perceive clearly how it may be reconciled to practice. The difference between the two conclusions is about four leagues in the two axes. The equatorial regions are found to have an elevation of two leagues more than they ought to have by the theory. This height of two leagues corresponds exactly with the greatest inequalities which have been produced on the surface of the globe by the motion of the sea, and the action of fluids. Here some illustration is necessary. At the time of the earth's formation, in consequence of the mutual attraction of its parts, and of its centrifugal force, it must have assumed a

* M. de Maupertuis, figure de la terre.

spheroidal figure, with its axes different by a 230th part. This would be the real figure of the earth while it remained in a state of liquefaction. But, after cooling for some time, the rarified vapours, like those in the tail or atmosphere of a comet, would condense, and fall on the surface in the form of air and water; and, when these waters begin to be agitated by a flux and reflux, sand, and other bodies, would be gradually transported from the poles towards the equatorial parts. This operation, when continued for some time, would necessarily sink the poles, and elevate the equator in the same proportion. The surface of the earth being likewise exposed to the winds, to the action of the air and of the sun; all these causes would concur with the tides in furrowing the earth, in scooping out valleys, in elevating the mountains, and in producing other superficial irregularities, none of which, perhaps, exceed a league in thickness, even at the equator. This inequality of two leagues may be supposed to be the greatest that can take place on the surface; for the highest mountains exceed not a league in height; and the most profound parts of the ocean, it is probable, are not above a league in depth. Thus my theory perfectly coincides with practice. The earth's equator could not, at first, be elevated more than six leagues and a half above the poles; but the changes produced on the surface might give it a still greater elevation. Natural history

history wonderfully supports this opinion; for, in the preceding discourse, we have proved, that, from the tides and other motions of the waters, have proceeded mountains, and all the other inequalities on the surface of the globe; and that, at great depths, as well as upon the greatest heights, bones, shells, and other relics of sea and land animals, have been discovered.

From what has been observed, it may be conjectured, that, in order to find primitive earth, and substances which have never been removed from their original stations, we must dig in countries near the poles, where the bed of unmoved earth will be thinner than in southern climates.

In fine, if the measurement by which the figure of the earth was determined be strictly scrutinized, we shall find that it is not altogether free from hypothetical reasoning: For it proceeded on the supposition that the earth was a regular curve: But, as the earth is liable to considerable and constant changes from a thousand causes, it is impossible that it could have retained any perfectly regular figure; and hence, agreeable to our theory, and the opinion of Newton, the poles might originally be only flattened a 230th part. Besides, though we have the exact length of a degree at the equator and polar circle, yet we have not the exact length of a degree in France; and the measures of M. Picard have never been confirmed. It may be added,

added, that the diminution and increase in the motion of the pendulum agree not with the conclusions drawn from measurement; and that, on the contrary, they correspond very nearly with the theory of Newton. These circumstances tend farther to convince us, that the poles are not depressed above a 230th part; and that, if there be any difference, it can proceed from nothing but the inequalities produced on the surface by the waters, and other external causes. But these inequalities are by no means so regular as to justify any hypothesis, which supposes the meridians to be ellipses, or any other perfect curves. Hence it appears, that, though many degrees should be successively measured in different regions, we cannot, by that alone, ascertain the exact depression of the poles, nor determine how much it exceeds or falls short of a 230th part.

May we not likewise conjecture, that, if the inclination of the earth's axis has been changed, this effect could not be produced but by the changes on the surface, since all the other parts are homogeneous; that this variation is, of course, too small to be perceived by astronomers; and that, if the earth be not disturbed by a comet, or some other external cause, its axis will for ever preserve its present and original inclination?

Not to omit any conjecture that seems reasonable, may we not suppose, that, as the mountains and other inequalities on the surface of
the

the earth, have originated from the action of the tides, those which we perceive in the moon have been produced by a similar cause? The mountains of the moon are indeed higher than those of the earth; but her tides are likewise stronger; because the earth, the size of which is much larger, raises the tides of the moon with a superior force. This effect would be greatly augmented, if the moon, like the earth, had a quick diurnal motion. But, as the moon uniformly presents the same face to the earth, the tides are raised only in proportion to the motion occasioned by her librations, which alternately expose to our view a small segment of her other hemisphere. This cause, however, must produce tides very different from those of our seas; and their effects will, of course, be much less considerable, than if the moon had possessed a diurnal revolution round her axis, equally quick as the rotation of the earth.

I should compose a volume equal to that of Burnet or Whiston, were I to extend the ideas presented by the above theory; and were I, in imitation of the last-mentioned author, to clothe them in a geometrical dress, I might add considerably to their importance. But I have always thought, that hypotheses, however probable, deserve not to be treated so pompously. It is apt to give them the air of quackery and imposition.

P R O O F S
OF THE
THEORY OF THE EARTH.

ARTICLE II.

Of the System of Whiston.*

THIS author begins his theory with a dissertation on the creation of the world. He alleges, that the account given of it by Moses is not properly understood; and that, in inquiries of this kind, men, contenting themselves with the most evident and superficial views, give too little of their attention to nature, reason, and philosophy. The common notions, he observes, concerning the six days work, are false; and the description of Moses is not an exact or philosophic account of the creation and origin of the universe, but only an historical

* See a new Theory of the Earth by Will. Whiston, London, 1708.

narrative of the formation of the terrestrial globe. The earth, in his estimation, formerly existed in chaos, and, at the time mentioned by Moses, it only received a form, situation, and consistence, necessary for the habitation of mankind. I shall not give a detail of Whiston's proofs, nor enter upon a formal refutation of them, but content myself with a short view of his theory, which will show it to be contrary to the scriptures, and, of course, that his proofs must be false. Besides, he treats this matter more like a polemical divine than a philosopher.

Leaving these false principles, he proceeds to some ingenious notions, which, though singular, will not, to those who are influenced by the enthusiasm of system, appear to be destitute of probability. He tells us, that the ancient Chaos, from which the earth originated, was the atmosphere of a comet; that the annual motion of the earth began when it received its new form; but that its diurnal motion commenced not till the fall of Adam; that the ecliptic cut the tropic of Cancer in a point precisely opposite to Paradise, which was situated on the north-west frontier of Assyria; that, before the deluge, the year began at the autumnal equinox, and that the orbits of the earth and planets were then perfect circles; that the deluge commenced on the 18th of November, in the year of the Julian period 2365, or 2349 before Christ; that, previous to the deluge, the solar and lunar
year

year were the same, and consisted exactly of 360 days ; that a comet, descending in the plane of the ecliptic to its perihelion, on the very day that the deluge began, made a near approach to the earth ; that there is a great heat in the bowels of the earth, which is constantly expanding from the centre to the circumference ; that the figure of the earth resembles an egg ; that the mountains are the lightest parts of the globe, &c. He then attributes to the deluge all the changes the earth has undergone, blindly adopts Woodward's theory, uses indiscriminately all that author's remarks on the present state of the earth ; but assumes more the air of an original, when he treats of its future condition. The earth, says Mr Whiston, will be consumed by fire ; and its destruction will be preceded by earthquakes, thunder, and hideous meteors ; the sun and moon will assume a dreadful aspect ; the heavens will seem to fall ; and the whole earth will be in flames. But, after the fire shall have devoured every impurity of this globe, and vitrified and rendered it transparent as the purest crystal, the saints and spirits of the blessed shall take possession of it, and there remain till the general judgment.

This hypothesis appears, at first view, to be extravagant and fantastical. But the author has managed his ideas with such dexterity, and placed them in so strong a light, that they no longer have the air of absolute chimeras. He has

adorned his subject with much science and ingenuity : And it is astonishing, that, from such a medley of strange notions, he should have been able to compose a system so plausible. But it is not to the vulgar that it has this brilliant appearance ; the learned are more easily deceived by the glare of erudition, and the force of new ideas. Mr Whiston was a celebrated astronomer. Accustomed to contemplate the heavens, to measure the motions of the stars, and to consider the great phænomena of nature, he could never imagine that this grain of sand, which we inhabit, occupied more the attention of its Creator than the universe, which contains, in the vast regions of space, millions of other suns and other worlds. He alleges, that Moses has not given us the history of the first creation of this globe, but only a detail of those circumstances which attended its receiving a form fit for the habitation of men, when the Almighty transformed it from the state of a comet to that of a planet. Comets, owing to the eccentricity of their orbits, are subject to dreadful vicissitudes : Sometimes, like that of 1680, they are a thousand times hotter than melted iron, and sometimes a thousand times colder than ice : They cannot, therefore, furnish habitation to any creatures of which we can form a conception ; or rather, they are altogether uninhabitable.

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The planets, on the contrary, are tranquil bodies ; their distances from the sun vary but little ; and their temperature continues so nearly the same, that it permits plants and animals to grow and to multiply.

In the beginning, says Mr. Whiston, God created the universe ; but the earth was then an uninhabitable comet, and subject to such alternate extremes of cold and heat, that its matter, being sometimes liquified and sometimes frozen, was in the form of chaos, or an abyfs, surrounded with utter darkness : *And darkness covered the face of the deep.* This chaos was the atmosphere of the comet, a body composed of heterogeneous materials, having its centre occupied with a globular, solid, hot nucleus, of about 2000 leagues in diameter, round which was an extensive mass of a thick fluid, mixed with heterogeneous and undigested materials, like the chaos of the ancients, *rudis indigestaque moles.* This great atmosphere contained few dry, solid, or earthy particles, and still less of water or air ; but it was amply filled with thick and heavy fluids, mixed, agitated, and jumbled together in the utmost confusion. Such was the condition of the earth when six days old : But, next day, that is, on the first day of the creation, when the eccentric orbit of the comet was changed into an ellipse, nearly circular, every thing assumed its proper place ; the different materials arranged themselves accord-

ing to their specific gravities; the heavy fluids sunk down, and left to the earthy, watery, and aerial substances, the superior regions. These also descended in the order of their gravities; first the earth, then the water, and, lastly, the air. In this manner, the immense volume of chaos was reduced to a moderate sphere, the centre of which is a solid body that still retains the heat it received from the sun, when formerly the nucleus of a comet. This heat may easily last 6000 years, since the comet 1680 would require 50,000 before it cooled. Round the solid and burning nucleus, at the centre of the earth, is placed the heavy fluid which descended first, and formed the great abyfs, upon which the earth floats like a cork on quick-silver. But as the earthy parts were originally mixed with a great body of water, they, in descending, drove before them a part of this water, which was confined there when the earth consolidated, and formed a stratum concentric with the heavy fluid that surrounds the nucleus. Thus, the great abyfs is composed of two concentric circles, the interior being a heavy fluid, and the superior water, upon which last the earth is immediately founded. From this admirable arrangement, produced by the atmosphere of a comet, are to be deduced the theory of the earth, and an explication of all its phænomena!

After the atmosphere of the comet had been freed from the solid and earthy particles, a pure
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air only remained, through which the rays of the sun instantly penetrated, and produced light: *Let there be light; and there was light.* The vast columns or beds of which the earth is composed, being formed with so much precipitation, is the reason why they differ so much in density; the heavier sunk deeper into the abyss than the lighter, and, of course, gave rise to mountains and valleys: These inequalities, before the deluge, were differently situated from what they are at present. Instead of that vast valley which contains the ocean, many small caverns were dispersed over the globe, each of which contained a part of the waters. The mountains were then at greater distances, and formed not large chains. But the earth was a thousand times more fertile, and contained a thousand times more inhabitants; and the life of man, and of the other animals, was ten times longer. All these effects were produced by the superior heat of the central fire, which gave birth to a greater number of plants and animals, and, at the same time, bestowed on them a degree of vigour that enabled them to exist long, and to multiply abundantly. But this heat had a miserable effect upon the dispositions of men and other animals: It augmented the passions, robbed man of his innocence, and diminished the sagacity of the brute creation. All creatures, except the fishes, who inhabited a colder element, felt the influence of the central heat, became vicious,

and merited death. This universal death was accordingly inflicted, on Wednesday the 28th day of November, by a dreadful deluge, which lasted 40 days and 40 nights, and was occasioned by the tail of a comet meeting with the earth, in returning from its perihelion.

The tail of a comet is the lightest part of its atmosphere. It is a transparent and subtile vapour-raised by the heat of the sun from the body of the comet. This vapour, which is composed of aerial and watery particles extremely rarified, follows the comet in its descent to its perihelion, and goes before the comet in its ascent, its situation being always opposite to the sun, as if it had an affection for the shade, and wished to avoid the scorching rays of the sun. This column of vapour is often of an immense extent; and its length always increases in proportion as the comet approaches nearer the sun. Now, as many comets descend below the annual orbit of the earth, it is not surprising that the earth should sometimes be involved in this vapour. This dreadful event happened at the time of the deluge. The tail of a comet, in two hours, will discharge a quantity of water equal to that contained in the whole ocean. In fine, this tail is what Moses calls the cataracts of heaven; *And the cataracts of heaven were opened.* The globe of the earth, when it meets with a comet's tail, must necessarily, in its passage through this body of vapour, appropriate
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part of its materials. Every thing that comes within the sphere of the earth's attraction must fall upon it, and must fall in the form of vapour, since the tail itself principally consists of that element. In this manner, rain may come from the heavens in such torrents, as to produce an universal deluge, and to surmount the tops of the highest mountains.

Our author, however, unwilling to go beyond the letter of the sacred writings, does not ascribe the deluge to this rain alone, which he has chosen to bring from so great a distance. He takes advantage of water wherever he can find it: The great abyfs, as we have seen, contains a considerable quantity. The earth, in its approach towards the comet, would feel the force of its attraction; the waters in the great abyfs would be so agitated with a motion similar to that of the tides, as would necessarily break the shell or crust in many places, and make the water rush out upon the surface: *And the fountains of the abyfs were opened.*

But how, it may be asked, was this vast collection of water, so liberally furnished by the great abyfs, and by the comet's tail, afterwards disposed of? Our author is not embarrassed by this circumstance. As soon as the earth escaped from the comet, the flux and reflux of the great abyfs necessarily ceased. From that moment the waters on the surface rushed down with violence by the same channels out of which they had

had issued. The great abyfs swallowed up not only its own water, but all that had been deposited by the comet, which it was sufficiently enabled to contain; because, during its agitation, and when it broke the crust, it had greatly enlarged its dimensions, by pushing the earth farther from it on all sides. It was at this time, likewise, that the earth, which was formerly a sphere, assumed its elliptical figure. This effect was produced by the centrifugal force occasioned by the diurnal motion of the earth, and by the attraction of the comet; for the earth, when passing through the tail of the comet, was so situated, that its equatorial parts were nearest that star; and, of course, the power of the comet's attraction, concurring with the earth's centrifugal force, elevated the equatorial regions with the greater facility, because the crust was broken in an infinite number of places, and because the flux and reflux of the abyfs pushed more violently against the equator than any where else.

This is the history Mr. Whiston gives of the creation, of the causes of the universal deluge, of the longevity of the Antedeluvians, and of the figure of the earth. All these difficult subjects seem to have given our author very little trouble. But he appears to be greatly puzzled concerning Noah's ark. In that dreadful confusion, produced by the conjunction of the tail of a comet, and by the waters of the great abyfs, and in that horrible period, when not only
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the elements of this globe were confounded, but when the heavens concurred with the bowels of the earth in producing new elements to increase the chaos, how is it to be imagined that the ark could float tranquilly, with its numerous and valuable cargo, upon the surface of the waves? Here our author struggles hard, in order to account for the preservation of the ark. But, as his reasoning upon this subject appears to be inconclusive, ill-imagined, and heterodox, I shall only observe, how hard it is for a man, who had explained objects so great and surprising, without having recourse to a supernatural power, to be stopped in his career by a trifling circumstance. But he chooses to risk drowning himself along with the ark, rather than to ascribe the preservation of this precious vessel to the interposition of the Almighty!

I shall only make a single remark upon this system, of which I have given a faithful abridgement. Whenever men are so presumptuous as to attempt a physical explanation of theological truths; whenever they allow themselves to interpret the sacred text by views purely human; whenever they reason concerning the will of the Deity, and the execution of his decrees; they must necessarily involve themselves in obscurity, and tumble into a chaos of confusion, like the author of this whimsical system, which, notwithstanding all its absurdities, has been received

ceived with great applause. Mr. Whiston neither doubted of the truth of the deluge, nor of the authenticity of the sacred writings. But, as physics and astronomy occupied his principal attention, he mistook passages of holy writ for physical facts, and for results of astronomical observations; and so strangely jumbled divinity with human science, that he has given birth to the most extraordinary system that perhaps ever did or ever will appear.

P R O O F S

OF THE

THEORY OF THE EARTH.

ARTICLE III.

Of Burnet's Theory.*

MR. BURNET is the first author who discovered enlarged views of the present subject, and who treated of it in a systematic manner. He was a man of genius and of taste : His work acquired great reputation, and was of course, criticised by many of the learned, and, among others, by Mr. Keill, who scrutinizing the subject as a geometer, demonstrated the errors of Burnet's theory in a treatise entitled, *An examination of the Theory of the Earth*. Mr. Keill likewise refuted the system of Whiston ; but he treated the latter in a manner very different from the former. He even appears, in many

* Thomas Burnet. Telluris theoria sacra, orbis nostri originem et mutationes generales, quas aut jam subiit, aut olim subiturus est, complectens. Londini 1681.

particulars,

particulars, to adopt the opinions of Whiston; and considers the notion, that the deluge was occasioned by the tail of a comet as exceedingly probable. But, to return to Burnet: His book is written with elegance. He knows how to paint the grandest images and the most magnificent scenes. His plan is elevated; but, being defective in proper materials, he often fails in the execution. His reasonings and his proofs are feeble; but the boldness with which he writes makes the reader lose sight of all his imperfections.

He begins with alleging, that the earth, before the deluge, was very different from what it is now. It was at first, says he, a fluid mass, composed of matters of every species, and of all kinds of figures, the heaviest of which descended to the centre, and formed a hard and solid body. The waters took their station round this body; and all lighter fluids rose above the water. Thus, between the coat of air, and that of water, a coat of oily matter was interposed. But, as the air was then full of impurities, and contained great quantities of earthy particles, these gradually subsided upon the coat or stratum of oil, and formed a crust composed of earth and oil: This crust was the first habitable part of the earth, and the first abode of man and other animals. The land thus formed was light, fat, and adapted to cherish the tenderness of the original germs. The surface of the earth was level and

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and uniform, without mountains, seas, or other inequalities. But it remained in this state about sixteen centuries only ; for the heat of the sun gradually drying the crust, produced, at first, superficial fissures or cracks only ; but, in process of time, these fissures penetrated deeper, and increased so much in their dimensions, that, at last, they entirely perforated the crust. In an instant, the whole earth split in pieces, and fell into the great abyss of waters which it formerly surrounded. This wonderful event was the universal deluge.

But all these masses of earth, in falling into the abyss, carried along with them vast quantities of air, and they dashed against each other, and accumulated and divided so irregularly, that great cavities filled with air were left between them. The waters gradually opened passages into these cavities, and, in proportion as the cavities were filled with the water, the surface of the earth began to discover itself in the most elevated places ; and, at last, the waters appeared no where but in those extensive valleys which contain the ocean. Thus our ocean is a part of the ancient abyss ; the rest of it remains in the internal cavities, with which the sea has still a communication. Islands and sea-rocks are the small fragments, and continents are the large masses of the ancient crust. As both the rupture and fall of this crust were effected in a sudden and confused manner, it is not surprising that

the surface of the present earth should be full of mountains, gulfs, plains, and irregularities of every kind.

This specimen is sufficient to give an idea of Burnet's system. It is an elegant romance, a book which may be read for amusement, but cannot convey any instruction. The author was ignorant of the chief phænomena of the earth, and a man of no observation. He has drawn every thing from imagination, which often acts both against truth and reason.

P R O O F S

OF THE

THEORY OF THE EARTH.

A R T I C L E IV.

Of the System of Woodward.*

OF this author it may be said, that he wanted to build an immense edifice upon a foundation less firm than sand, and to construct a world with dust; for, he asserts, that the earth, at the time of the deluge, suffered a total dissolution. In perusing his book, the first idea which presents itself is, that this dissolution was effected by the waters of the great abyss. He alleges, that, at the command of God, the abyss suddenly opened, and diffused such an enormous quantity of water on the surface, as was sufficient to cover the tops of the highest mountains; and

* An Essay towards the Natural History of the Earth, by John Woodward.

that God suspended the law of cohesion, which instantly reduced every solid substance into a powder, &c. He did not consider, that, by these suppositions, he added to the miracle of the universal deluge many other miracles, or, at least, physical impossibilities, which accord neither with the scriptures, nor with the principles of mathematics and of natural philosophy. But as this author has the merit of collecting many important observations, and as he knew better than any former writer the materials of which the globe is composed, his system, though ill conceived and worse arranged, has seduced, by the lustre of a few striking facts, many weak men into a belief of his general conclusions.

We shall now give a short view of his theory, by which we will be enabled to do justice to the merit of the author, and put the reader in a condition to judge of the futility of his system, and of the falsehood of some of his remarks. Mr. Woodward informs us, that he recognised with his own eyes all the materials of which the earth in England is composed, from the surface to the greatest depths that had been dug; that they were all disposed in beds, or strata; and that, in many of these beds, there are shells and other productions of the sea. He then adds, that he was assured by his friends and correspondents, that in all the other countries of the world, the earth was composed of the same materials; and that shells are found, not only in the
plains,

plains, and in some particular parts, but on the highest mountains, in the deepest pits, and in an infinite number of different places. He observed, that the beds were all horizontal, and placed over each other, like matters transported by the waters, and deposited in the form of sediment. These general remarks, which are founded in truth, are followed with some particular observations, by which he demonstrates, that the fossil shells incorporated with the strata are real sea-shells, and not peculiar minerals, or *lusus nature*, &c.

To these observations, though partly made before him, he has added others of a more suspicious nature. He asserts, that the materials of the different strata are arranged according to their specific gravities. This assertion is not consistent with truth: For we every day see solid rocks placed above clay, sand, pit-coal, bitumen, and other comparatively light bodies. If, indeed, it were uniformly found, through the whole earth, that the upper stratum was bitumen, followed successively by strata of chalk, marl, clay, sand, stone, marble, and metals, it would, in that case, be probable that all those materials had been precipitated at once: And this our author affirms with confidence, though the most superficial observer needs only his eyes to convince him, that heavy strata are often found above light ones; and, consequently, that these sediments could not be deposited at the same time, but must have been transported and

deposited by the ocean at successive periods. As this is the foundation of Woodward's system, and is manifestly false, we shall follow him no farther than to show how an erroneous principle produces false relations and bad conclusions.

All the strata which compose the earth, says our author, from the tops of the highest mountains to the deepest mines, are placed according to their respective specific gravities. Hence, he concludes, the whole must have been in a state of dissolution, and precipitated at the same time. But at what time, in what menstruum, was it dissolved? In the water, says Mr. Woodward, and at the time of the deluge. But there is not water enough on the globe to produce this effect; for there is more earth than water; and the bottom of the sea itself is earth. Very well, he replies: But there is enough of water in the central parts of the earth; and nothing more was wanting than to bestow on it the power of dissolving every terrestrial substance, except sea-shells; to find a proper method of making the waters return to the abyss; and to make all this correspond with the history of the deluge. Behold a system, of which the author could not prevail on himself to form a doubt; for, when it was objected to him, that water could not dissolve water, rocks, and metals, especially in forty days, the time of the waters remaining on the earth; he replied simply, that the event, however, did happen. When it was demanded

demanded of him, how the waters of the abyſs could diſſolve the whole earth, and yet preſerve the ſhells? He answered, that he never proved that this water was a diſſolvent ; but that, from facts, it was clear that the earth had been diſſolved, and that the ſhells were preſerved. Laſtly, When it was demonſtrated to him, that his ſyſtem was uſeleſs, as it was neither ſupported by reaſon nor by facts, he ſaid, We had only to ſuppoſe that, at the time of the deluge, the laws of gravity and of coheſion were ſuddenly ſtopped, and, upon this ſuppoſition, the diſſolution of the ancient world admitted of an eaſy explanation. But, it was obſerved to him, if the force of coheſion was ſuſpended, Why were not the ſhells diſſolved along with the reſt ? Here he gave a harangue on the organization of ſhells and of animal bones, tending to prove that their texture was fibrous, and different from that of minerals ; that their coheſion was likewise different ; and that, after all, we have only to ſuppoſe that the powers of gravity and of coheſion did not entirely ceaſe, but that they were diminiſhed to ſuch a degree, as enabled them to diſſolve the parts of minerals, but not thoſe of animals. I ſhall conclude with remarking, that our author's philoſophy was not equal to his talent for obſervation ; it is therefore unneceſſary to give a formal refutation of abſurd notions, eſpecially when they proceed upon conjectures which are contrary both to the laws of probability and of mechanics.

P R O O F S
OF THE
THEORY OF THE EARTH,

A R T I C L E V.

Examination of some other Systems.

THE three hypotheses formerly animad-
verted upon have many things in com-
mon: They all agree in this, that, at the time
of the deluge, both the external and internal
form of the earth was changed. But none of these
theorists considered, that the earth, before the de-
luge, was inhabited by the same species of men
and animals; and, consequently, that it must have
been nearly the same, both in figure and structure,
as it is at present. We are informed by the sacred
writings, that, before the deluge, there were ri-
vers; seas, mountains, and forests; that most of
these mountains and rivers remained nearly in
their former situation; the Tigris and Euphrates,
for

for example, ran through Paradise ; that the Armenian mountain on which the ark rested, was, at the deluge, one of the highest mountains of the earth, as it is at this day ; and that the same plants and the same animals, which inhabited the earth before the deluge, continue still to exist ; for we are told of the serpent, of the crow, and of the pigeon that carried the olive-branch into the ark. Tournefort indeed alleges, that there are no olives within 400 leagues of Mount Ararat, and affects to be witty on this head. It is, however, indisputable, that there were olives in the neighbourhood of this mountain at the time of the deluge ; for Moses assures us of the fact in the most express manner. Besides, it is not surprising, that, in the course of 4000 years, the olives should be extirpated in these provinces, and multiplied in others. It is, therefore, contrary both to scripture and reason, that these authors have supposed the earth, before the deluge, to have been totally different from what it is now ; and this opposition between their hypotheses and the sacred writings, as well as sound philosophy, is sufficient to discredit their systems, although they should correspond with some phenomena *. Burnet, who wrote first, gives neither facts nor observations in support of his system. Woodward's book is only a short essay, in which he promises much more than he was able to perform ; it is only a project, with-

out any degree of execution. He makes use of two general remarks, 1. That the earth is everywhere composed of materials which had formerly been in a state of fluidity, and which had been deposited by the waters in horizontal beds, 2. That, in the bowels of many parts of the earth, there are an infinite number of sea-bodies. To account for these facts, he has recourse to the universal deluge; or rather, he appears to employ these as proofs of the deluge. But, like Burnet, he falls into evident contradictions; for it is absurd to suppose, with these authors, that, before the deluge, there were no mountains, since we are expressly told, that the waters rose 15 cubits above the tops of the highest mountains. On the other hand, it is not said that the waters destroyed or dissolved the mountains. In place of this extraordinary dissolution, the mountains remained firm in their original situations, and the ark rested upon the one which was first deserted by the waters. Besides, it is impossible to imagine, that, during the short time the deluge continued, the waters could dissolve the mountains, and the whole fabric of the earth. Is it not absurd to suppose, that, in the space of forty days, the hardest rocks and minerals were dissolved by simple water? Is it not a manifest contradiction to admit this total dissolution, and yet to maintain that shells, bones, and other productions of the sea, were able to resist a menstruum to which the most solid materials

terials had yielded? Upon the whole, I cannot hesitate in pronouncing, that Woodward, though furnished with excellent facts and observations, has produced but a weak and inconsistent theory.

Whiston, who wrote last, has greatly improved upon the other two; and, though he has given loose reins to his imagination, it cannot be said that he falls into contradiction. He advances many things which are incredible; but they are neither absolutely nor apparently impossible. As we are ignorant of what materials the centre of the earth is composed, he thinks himself intitled to suppose it a solid nucleus, surrounded with a ring of heavy fluid matter, and then follows a ring of water, upon which the external crust is supported. In this ring of water, the different parts of the crust sunk more or less in proportion to their gravities, and gave rise to mountains and inequalities on the surface of the earth. But our astronomer here commits a blunder in mechanics. He considered not, that the earth, on this supposition, must have formed one uniform arch; and, consequently, that it could not be supported by the water, and far less could any part of this arch sink deeper than another. If this be excepted, I doubt whether he has fallen into any other physical blunder: He has, however, committed many errors both in metaphysics and theology. In fine, it cannot be denied absolutely, that the earth, in meeting with the tail of a comet, would be de-
luded,

lugged, especially if it be allowed to the author, that the tails of comets contain watery vapours. Neither is it absolutely impossible, that the tail of a comet, in returning from its perihelion, should burn the earth, if we suppose, with Mr. Whiston, that the comet passed very near the sun's body. The same observations may be made upon the rest of his system. But, though his notions be not absolutely impossible, when taken separately, they are so exceedingly improbable, that the whole assemblage may be regarded as exceeding the bounds of human credulity.

These three are not the only books which have been written upon the theory of the earth. In 1729, M. Bourguet published, along with his *Philosophical Letters on the formation of Salts, &c.* a memoir, in which he gives a specimen of a system which he had projected; but the execution of it was prevented by the death of the author. It must be acknowledged, that no man was more industrious and acute in making observations, and in collecting facts. To him we are indebted for remarking the correspondence between the angles of mountains, which is the chief key to the theory of the earth. He arranges the materials he had collected in the best order. But, with all these advantages, it is probable, that he would not have succeeded in giving a physical history of the changes which have happened in the earth; and he appears not to have discovered the causes of those effects which
he

he relates. To be convinced of this remark, we have only to take a view of the propositions he deduces from those phænomena which must have been the foundation of his theory. He says, that the earth was formed at once, and not successively; that its figure and disposition demonstrate that it was formerly in a fluid state; that the present condition of the earth is very different from what it was some ages after its first formation; that the matter of the globe was originally more soft than after its surface was changed; that the condensation of its solid parts diminished gradually with its velocity; so that, after a certain number of revolutions round its own axis, and round the sun, its original structure was suddenly dissolved; that this happened at the vernal equinox; that the sea-shells insinuated themselves into the dissolved matters; that the earth, after this dissolution, assumed its present form; and that, as soon as the fire or heat operated upon it, its consumption gradually began, and, at some future period, it will be blown up with a dreadful explosion, accompanied with a general conflagration, which will augment the atmosphere, and diminish the diameter of the globe; and then the earth, in place of strata of sand or clay, will consist only of beds of calcined materials, and mountains composed of amalgams of different metals.

“This is a sufficient view of the system which M. Bourguet designed to compose. To guess at

the past, and to predict the future, nearly in the same manner as others have guessed and predicted, requires but a small effort of genius. This author had more erudition than found and general ideas. He appears not to have had the capacity of forming enlarged views, or of comprehending the chain of causes and effects.

In the *Leipsic Transactions*, the celebrated Leibnitz published a sketch of an opposite system, under the title of *Protogæa*. The earth, according to Bourguet and others, was to be consumed by fire. But Leibnitz maintains, that it originated from fire, and that it has undergone innumerable changes and revolutions. At the time that Moses tells us the light was divided from the darkness, the greatest part of the earth was in flames. The planets, as well as the earth, were originally fixed and luminous stars. After burning for many ages, he alleges, that they were extinguished from a deficiency of combustible matter, and that they became opaque bodies. The fire, by melting the matter produced a vitrified crust; and the basis of all terrestrial bodies is glass, of which sand and gravel are only the fragments. The other species of earth resulted from a mixture of sand with water and fixed salts; and, when the crust had cooled, the moist particles, which had been elevated in the form of vapour, fell down, and formed the ocean. These waters at first covered the whole surface, and even overtopped the highest

highest mountains. In the estimation of this author, the shells, and other spoils of the ocean, which every where abound, are indelible proofs that the earth was formerly covered with the sea ; and the great quantity of fixed salts, of sand, and of other melted and calcined matters shut up in the bowels of the earth, demonstrate, that the conflagration had been general, and that it had preceded the existence of the ocean. These ideas, though destitute of evidence, are elevated, and bear conspicuous marks of ingenuity. The thoughts have a connection, the hypotheses are not impossible, and the consequences which might be drawn from them are not contradictory. But the great defect of this theory is, that it applies not to the present state of the earth. It only explains what passed in ages so remote, that few vestiges remain ; a man may, therefore, affirm what he pleases, and what he says will be accompanied with more or less probability, in proportion to the extent of his talents. To maintain, with Whiston, that the earth was originally a comet, or with Leibnitz, that it was a sun, is to assert what is equally possible or impossible ; it would, therefore, be ridiculous to investigate either by the laws of probability. The instantaneous creation of the world destroys the notion of the globe's being covered with the ocean, and of that being the reason why sea-shells are so much diffused through different parts of the earth ; for, if that had

had been the case, it must of necessity be allowed, that shells, and other productions of the ocean, which are still found in the bowels of the earth, were created long prior to man, and other land-animals. Now, independent of scripture-authority, is it not reasonable to think that the origin of all kinds of animals and vegetables is equally ancient ?

M. Scheutzer, in a dissertation addressed to the Academy of Sciences in 1708, attributes, like Woodward, the change, or rather new creation of the globe, to the deluge. To account for the formation of mountains, he tells us, that God, when he ordered the waters to return to their subterraneous abodes, broke, with his Almighty hand, many of the horizontal strata, and elevated them above the surface of the earth, which was originally level. The whole dissertation was composed with a view to support this ridiculous notion. As it was necessary that these eminences should be of a solid consistence, M. Scheutzer remarks, that God only raised them from places which abounded in stones. Hence, says he, those countries, like Switzerland which are very stony, are likewise mountainous; and those, like Flanders, Holland, Hungary, and Poland, which are mostly composed of sand and clay to great depths, have few or no mountains *.

* Vid. Hist. de l'Acad. 1708^e p. 32.

This author, like Woodward, blends physics and theology ; and, though he has made some good observations, the systematic part of his work is weaker and more puerile than that of any of his predecessors. He has even descended to declamation, and absurd pleasantries. The reader, if he desires to see them, may consult his *Piscium Querelæ*, &c. not to mention his *Physica Sacra*, consisting of several volumes in folio, a weak performance, fitter for the amusement of children than the instruction of men.

Steno, and some others, have attributed the origin of mountains, and other inequalities upon the surface of the earth, to particular inundations, earthquakes, &c. But the effects of these secondary causes could produce nothing but slight changes. These causes may co-operate with the first cause, namely, the tides, and the motion of the sea from east to west. Besides, Steno has given no theory, nor even any general facts, upon this subject *.

Ray alleges, that all mountains have been produced by earthquakes, and has written a treatise to prove the point. When we come to the article of volcano's, we shall examine the foundation of this opinion.

We cannot omit observing here, that Burnet, Histon, Woodward, and most other authors, are fallen into an error which deserves to be rectified. They uniformly regard the deluge as

* Vide Dissert. de Solido intra Solidum nato, &c.

an effect within the compass of natural causes, although the scripture represents it as an immediate operation of the Deity. It is beyond the power of any natural cause to produce on the surface of the earth a quantity of water sufficient to cover the highest mountains: And, although a cause could be imagined adequate to this effect, it would still be impossible to find another cause capable of making the waters disappear. Granting that Whiston's water proceeded from the tail of a comet, we deny that any of them could issue from the abyfs, or that the whole could return into it; for the abyfs, according to him, was so environed and pressed on all sides by the terrestrial crust, that it was impossible the comet's attraction could produce the least motion in the fluid it contained, far less any motion resembling the tides: Hence, not a single drop could either proceed from, or enter into, the great abyfs. Unless, therefore, it is supposed, that the waters which fell from the comet were annihilated by a miracle, they would for ever have remained on the surface, and covered the tops of the highest mountains. The impossibility of explaining any effect by natural causes, is the most essential character of a miracle. Our authors have made several vain efforts to account for the deluge. Their errors in physics, and in the secondary causes they employ, prove the truth of the fact, as related in scripture, and demonstrate, that the universal deluge could not be accom-

accomplished by any other cause than the will of the Deity.

Besides, it is apparent, that it was not at one time, nor by the sudden effect of a deluge, that the sea left uncovered those continents which we inhabit: it is certain, from the authority of scripture, that the terrestrial Paradise was in Asia, and that Asia was inhabited before the deluge; consequently, the waters, at that period, covered not this large portion of the globe. The earth, before the deluge, was nearly the same as now. This enormous quantity of water, poured out by Divine justice upon guilty men, destroyed every living creature; but it produced no change on the surface of the earth; it destroyed not even the plants; for the pigeon returned to the ark with an *olive branch* in her bill.

Why then should we suppose, with many naturalists, that the waters of the deluge totally changed the surface of the globe, even to the depth of two thousand feet? Why imagine that the deluge transported those shells, which are found at the depth of seven or eight hundred feet, immersed in rocks and in marble? Why refer to this event the formation of hills and mountains? And how is it possible to imagine, that the waters of the deluge transported banks of shells of 100 leagues in length? I perceive not how they can persist in this opinion, unless they admit a double miracle, one to create water, and

another to transport shells. But as the first only is supported by holy writ, I see no reason for making the second an article of faith.

On the other hand, if the waters of the deluge had retired suddenly, they would have carried off such immense quantities of mud and soil, as would have rendered the land unfit for culture till many ages after this inundation. In the inundation which happened in Greece, the country that was covered remained barren for three centuries*. Thus the deluge ought to be regarded as a supernatural mode of chastising the wickedness of men, not as an effect proceeding from any natural cause. The universal deluge was a miracle, both in its cause and in its effects. It appears from the sacred text, that the sole design of the deluge was the destruction of men and other animals, and that it changed not in any manner the surface of the earth; for, after the retreat of the waters, the mountains, and even the trees, kept their former stations, and the land was suited for the culture of vines and other fruits of the earth. It might be asked, if the earth was dissolved in the waters, or, if the waters were so much agitated as to transport the shells of India into Europe, how the fishes, which entered not into the ark, were preserved?

The notion, that the shells were transported and left upon the land by the deluge, is the ge-

* Vide *acta erudit.* Lips. 1691, p. 100.

neral opinion, or rather superstition, of naturalists. Woodward, Scheutzer, and others, call petrified shells the remains of the deluge; they regard them as medals or monuments left us by God of this dreadful catastrophe, that the memorial of it might never be effaced among men. Lastly, they have embraced this hypothesis with so blind a veneration, that their only anxiety is to reconcile it with holy writ; and, in place of deriving any light from observation and experience, they wrap themselves up in the dark clouds of physical theology, the obscurity and littleness of which derogate from the simplicity and dignity of religion, and present to the sceptic nothing but a ridiculous medley of human conceits and divine truths. To attempt an explanation of the universal deluge and of its physical causes; to pretend to give a detail of what passed during this great revolution; to conjecture what effects have resulted from it; to add facts to the sacred writings, and to draw consequences from these interpolations; is not this a presumptuous desire of scanning the power of the Almighty? The natural wonders wrought by his beneficent hand, in a uniform and regular manner, are altogether incomprehensible; his extraordinary operations, or his miracles, ought, therefore, to impress us with an awful astonishment, and a silent respect.

It may still be urged, that, as the universal deluge is an established fact, is it not lawful to rea-

son upon its consequences? True. But you must commence with acknowledging, that the deluge could not possibly be the effect of any physical cause; you must regard it as an immediate operation of the Deity; you must content yourself with what is recorded in scripture; and you must, above all, avoid blending bad philosophy with the purity of divine truth. After taking these precautions, which a respect for the counsels of the Almighty requires, what remains for examination upon the subject of the deluge? Do the sacred writings tell us that the mountains were formed by the deluge? They tell us the reverse. Do they inform us that the agitation of the waters was so great, as to raise the shells from the bottom of the ocean, and to disperse them over the face of the earth? No: The ark moved gently on the surface of the waters. Do they tell us, that the earth suffered a total dissolution? By no means. The narration of the sacred historian is simple and true; that of naturalists is complicated and fabulous.

P R O O F S

OF THE

THEORY OF THE EARTH.

A R T I C L E VI.

Geography.

THE surface of the earth is not, like that of Jupiter, divided into alternate bands or belts, parallel to the equator. On the contrary, it is divided, from one pole to the other, into two belts of earth, and two of sea. The first and principal belt is the ancient Continent, the greatest length of which is a line commencing at the most eastern point of the north of Tartary, and extending from thence to the neighbourhood of the gulf of Linchidolin, where the Russians fish whales; from thence to Tobolski; from Tobolski to the Caspian sea; from the Caspian sea to Mecca; from Mecca to the western part of the country inhabited by the Galli in
I 3 Africa;

Africa ; from thence to Monoemuci, or Monomotapa ; and, lastly, to the Cape of Good Hope. This line is about 3600 leagues in length, and is never interrupted but by the Caspian and the Red Seas, the breadth of which is inconsiderable, and ought not to be regarded, especially as, like our seasons, the whole surface of the globe is divided into four parts only.

This greatest length of the Old Continent lies in a diagonal line ; for, if measured by a meridian, it will appear, that, from the northernmost point of Lapland to the Cape of Good Hope, exceeds not 2500 leagues ; and that this line, though shorter, meets with greater interruptions from the Baltic and Mediterranean. With regard to all other lines which could be drawn under the same meridians in the Old Continent, they must still be shorter than those we have mentioned. For example, from the most southern point of the Island of Ceylon to the northernmost coast of Nova Zembla, is 1800 leagues. In the same manner, if the Continent be measured by lines parallel to the equator, its greatest length, without much interruption by seas, will stretch from Trefana, on the west coast of Africa, to Ninpo, on the east coast of China, which is about 2800 leagues. Another line may begin near Brest, and extend to the coast of Chinese Tartary, which will be nearly 2300 leagues. From Bergen in Norway, to the coast of Kamtschatka, is only 1800 leagues. All these lines
are

are much shorter than the first. Hence the greatest length of the Old Continent extends from the eastern point of Tartary to the Cape of Good Hope, and is about 3600 leagues. See *plate I.*

This line may be considered as the middle of the ancient Continent; for, in measuring the surface on each side of it, I find, that on the left, there are 2,471,092 $\frac{3}{4}$ square leagues; and, on the right, there are 2,469,687, which is an equality so astonishing, as to render it extremely probable that this line, which is the longest, at the same time really divides the contents of the ancient Continent.

Hence the Old Continent consists of about 4,940,780 square leagues, which is a fifth part of the surface of the globe, and may be regarded as a large belt of earth, with an inclination to the equator of about 30 degrees.

The New Continent is another belt of earth, the greatest length of which may be taken from the mouth of the river Plata to the lake of the Assiniboils. This line passes from the mouth of the river Plata to Lake Caracara; from thence to Mataguais, Pocona, Zongo, Mariana, Morua, St. Fe, and Carthagenas; then it passes through the gulf of Mexico to Jamaica and Cuba; from thence along the peninsula of Florida, through Apalache, Chicachas; and from thence to St. Louis, Fort le Sueur, and terminates in the country bordering on Lake Assiniboils,

boils, the extent of which is unknown. *See plate II.*

This line is interrupted only by the Gulf of Mexico, (which may be considered as a Mediterranean sea,) is about 2500 leagues in length, and divides the New Continent nearly into two equal parts, that on the left containing $1,069,286\frac{5}{8}$ leagues square, and that on the right $1,070,926\frac{1}{2}$. It is the middle of the belt of land called the New Continent, and is likewise inclined to the equator about 30 degrees, but in an opposite direction; for that of the Old Continent extends from the north-east to the south-west; but that of the New Continent from north-west to south-east. The superficial contents of the Old and New Continents are about 7,080,993 square leagues, not near a third part of the surface of the globe, which contains 25,000,000 square leagues.

Of these lines, which divide the Continents into two equal parts, it may be remarked, that they both terminate at the same degrees of north and south latitude; and that the two Continents make mutual advances, or projections, exactly opposite to each other; namely, those on the African coast, from the Canary Isles to Guiney; and those of America, from Guiana to the mouth of the Rio-Janeiro.

It is, therefore, apparent, that the most ancient lands on the globe are those which extend from 200 to 250 leagues on each side of the two lines
above

above described. Agreeable to this idea, which is founded on the observations already made, we find that, in the Old Continent, the most ancient countries of Africa are those which stretch from the Cape of Good Hope to the Red Sea and Egypt, and are about 500 leagues broad; and, consequently, that the whole western coast of Africa, from Guiney to the Straits of Gibraltar, are new lands. In the same manner, if we trace this line through Asia, and include an equal breadth, we shall find, that the most ancient countries are, the two Arabia's, Persia, Georgia, Turcomania, a part of Independent Tartary, Circassia, part of Muscovy, &c.; and, of course, that Europe, and perhaps also China, and the eastern part of Tartary, are comparatively new countries.

In the New Continent, we shall likewise find, that Terra Magellanica, the eastern part of Brasil, of the country of the Amazons, of Guiana, and of Canada, are new lands, when compared with Tucuman, Peru, Terra Firma, the islands in the Gulf of Mexico, Florida, the Mississippi, and Mexico. To these observations may be added two remarkable facts. The Old and New Continents are nearly opposite to each other. The Old Continent extends farther north of the equator than south; but the New, farther south than north. The centre of the Old Continent lies in the 16th or 18th degree of north latitude; and the centre of the New Continent lies in the
16th

16th or 18th degree of south latitude, as if they were intended to counterbalance each other. There is another singular analogy between the two Continents, though it appears to be chiefly the effect of accident. Both Continents might be divided into two portions, which would be surrounded on all sides by the sea, except the two small isthmus's of Suez and Panama.

These general observations on the division of the globe are the result of an attentive survey. We shall not, upon this foundation, erect hypotheses, or indulge in reasonings, which might lead to false conclusions. But, as the division of the globe has not hitherto been considered under this point of view, I shall hazard a few remarks. It is not a little singular, that the longest line which can be drawn upon the two Continents should, at the same time, divide them into two equal parts. It is not less remarkable, that these two lines should commence and terminate at the same degrees of latitude, and have the same inclination to the equator. These relations may lead to general conclusions, of which we are still ignorant. We shall afterwards examine, in detail, the inequalities in the figure of the two Continents, and shall here only remark, that the most ancient countries should be found in the neighbourhood of the above lines, and should, at the same time, have the highest elevation; and that the more recent lands should
be

be most remote from these lines, and likewise lie lower. Agreeable to this idea, the newest countries in America should be the land of the Amazons, Guiana, and Canada. In examining the map of these countries, we perceive that they are every where divided by numberless lakes and rivers, which is a still stronger indication of their recent origin. On the other hand, the regions of Tucuman, Peru and Mexico, are high mountains, and situated near the line that divides the continent; circumstances which seem to prove the superior antiquity of these countries. Africa is also extremely mountainous, and at the same time very ancient. In this part of the globe, Egypt, Barbary, and the western coast, as far as Senegal, can only be considered as new lands. Asia is perhaps the most ancient of all countries, especially Arabia, Persia, and Tartary. But the inequalities of this great division of the globe, as well as those of Europe, shall be treated of in a separate article. We shall only remark, in general, that Europe is a new country, as appears from those universal traditions concerning migrations of different nations, and the origin of arts and sciences. It is not long since Europe was full of marshes and forests. But, in countries anciently inhabited, there are few woods, lakes, or marshes, but a great deal of heath and shrubs, and many high mountains, with dry and barren tops; for men destroy woods, drain marshes and lakes, and, in process

process of time, give an appearance to the face of the earth totally different from that of uninhabited or newly-peopled countries.

A small portion of the globe only was known to the ancients. The whole of America, the Artic Circle, Terra Australis and Magellanica, and a great part of the interior regions of Africa, were unknown to them. They knew not that the Torrid Zone was inhabited, although they had sailed round Africa. About 2200 years ago, Neco King of Egypt furnished some vessels to the Phœnicians, who sailed down the Red Sea, doubled the Cape of Good Hope, and the third year after their departure they entered the Mediterranean by the straits of Gibraltar*. The ancients, notwithstanding, were totally ignorant of the polarity of the loadstone, although they knew its power of attracting iron; they knew not the cause of the tides; and they were uncertain whether the ocean surrounded the globe. Some of them, indeed, suspected that it might be so; but these conjectures were so ill founded, that none of them ever dreamed of its being possible to circumnavigate the earth. Magellan, in the year 1519, was the first who attempted this great voyage; and he accomplished it in 112 $\frac{1}{2}$ days. Francis Drake, in the year 1577, was the second; and he performed it in 1056 days. Thomas Cavendish set out upon this voyage in 1586, and finished it in 777 days.

* See Herodotus, lib. 4.

These celebrated navigators were the first who gave a physical demonstration of the sphericity and extent of the circumference of the earth. The ancients, though they travelled much, had no adequate idea of the extent of the globe. They were equally ignorant of the trade-winds, which are so useful in long voyages. Their limited knowledge in geography, therefore, should not surprise us, especially when it is considered, that, notwithstanding the advantages derived from the mathematical sciences, and from the discoveries of navigators, many points remain still undetermined, and vast regions are yet undiscovered. Of the countries in the neighbourhood of the south pole, we only know that they exist, and that they are separated from the other continents by the ocean*. Much, likewise, remains to be discovered concerning the lands near the north pole: And it is a subject of regret, that, for a century past, the ardour for discovering new countries has greatly abated. The nations of Europe seem, and perhaps they are right, more disposed to increase the value of those countries they have already discovered, than to acquire new territories.

The discovery, however, of the Southern Continent would be a grand object of curiosity, and might be attended with the greatest advantages. A few of its coasts have been recognised; but those navigators, who have attempted

* Captain Cooke, in his late voyage, has demonstrated, in the completest manner, that no continent exists near the south pole.

this discovery, have always been prevented from reaching land by large bodies of ice. The thick fogs which infest those seas form another obstacle. But, notwithstanding all these inconveniencies, it is probable, that, by setting out from the Cape of Good Hope at different seasons, part of this new world might still be discovered.

Another method might, perhaps, be attended with more success. To avoid the fogs and the ice, the discovery might be attempted, by departing from Baldivia, or some other port on the coast of Chili, and traversing the south sea under the 50th degree of south latitude. This navigation appears not to be hazardous; and it is probable that it would be attended with the discovery of new lands; for the regions about the south pole, still unknown, are so extensive, that they may be computed to be about a fourth part of the globe; and, consequently, may contain a country as large as the whole of Europe, Asia, and Africa.

While we remain ignorant of this part of the earth, we cannot determine the proportion the surface of the land bears to that of the ocean; from what we do know, it appears that there is more sea than land.

To acquire an idea of the vast quantity of water in the ocean, we must suppose a medium depth, for example, that of 200 fathoms, or the sixth part of a league. Upon this supposition, there is as much water in the ocean as would be
sufficient

sufficient to cover the whole globe to the depth of 600 feet; or, if collected into one mass, it would form a globe of 60 leagues in diameter.

It is alleged by navigators, that the latitudes near the south pole are much colder than the same latitudes towards the north. But this opinion seems to have no foundation. It appears to have been adopted from the circumstance of ice appearing in latitudes where none is found in the northern seas. But this effect may be owing to some peculiar causes. After the month of April, there is no ice on this side of 67 or 68 degrees of north latitude; and the savages of Acadia and of Canada say, that if the ice be not melted in April, it indicates a cold and rainy summer. The year 1725 was distinguished by an almost perpetual rain; and, in April, the ice in the northern seas was not only not melted at the 67th degree, but, on the 15th of June, it was found in lat. 41 or 42*.

Great quantities of floating ice appear in the north seas, especially at considerable distances from land. They come from the Tartarean sea, into that of Nova Zembla and other parts of the Frozen Ocean. I have been assured, by people worthy of credit, that an English Captain, called Manson, instead of searching for a passage to China between the northern lands, directed his course straight to the pole till he arrived within two degrees of it; and that, in this course, he

* See l'Hist. de l'Acad. année 1727.

found an open sea, and no ice; which is a clear proof that the ice is always formed near the land, and never in an extensive sea: For, though it should be supposed, contrary to probability, that the cold was so intense at the pole as to freeze the surface of the sea, it is still inconceivable how these enormous floating masses could be formed, without being attached to the land, from which they are again separated by the heat of the sun. Two vessels sent by the East India Company, in 1739, to discover land in the south seas, found boards of ice in lat. 47 or 48; but they were not very distant from the shore, which was in view, though the vessels could not make their landing good*. These boards of ice must have been detached from the lands in the neighbourhood of the south pole; and it may be conjectured that they follow the course of some large rivers in these unknown regions, in the same manner as the Oby, the Jenisca, and other great rivers that fall into the north seas, carry down boards of ice, which shut up, during the greatest part of the year, the straits of Waigat, and render the sea of Tartary, by this course, altogether inaccessible; while, beyond Nova Zembla, and nearer the pole, where there is little land and few rivers, boards of ice are less frequent, and the sea is more navigable. Hence, if any farther attempts be made to find a passage to China and Japan by the north seas,

* See on this subject a chart by M. Buache, 1739.

It will, perhaps, be necessary to keep at a distance from the land and the ice, to steer directly towards the pole, and to explore the most open seas, where unquestionably there is little or no ice: For it is well known, that salt water can take on a greater degree of cold, without freezing, than fresh water after it is congealed; consequently, the excessive cold at the pole may render the sea colder than ice, without freezing its surface. Besides, at 80 or 82 degrees, the sea, though mixed with snow and fresh water, is never frozen, except near the coasts. From the united testimony of several navigators, it is apparent, that there is a passage from Europe to China by the north sea: The reason why it has so often been in vain attempted is obvious. Fear prevented the undertakers from keeping at a sufficient distance from the land, and from approaching the pole, which they probably imagined to be an immense rock.

William Barents, however, who, like many others, had run aground in his voyage, never doubted the existence of such a passage, or that, if he had kept farther from land, he would have found an open sea without ice. The Russian navigators sent by the Czar to reconnoitre the north sea, relate, that Nova Zembla is not an island, but a part of Tartary, and that, to the north of it, there is a free and open sea. A Dutch voyager affirms, that whales are occasionally thrown upon the coasts of Corea and of

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Japan, with European harpoons sticking in their backs. Another Hollander alleges, that he had penetrated to the pole itself, and assures us, that it was as warm as at Amsterdam in summer. One Goulden, an Englishman, who had made above thirty voyages to Greenland, related to Charles II. that two Dutchmen, who sailed along with him, having been unsuccessful in fishing off the coast of the Isle of Edges, resolved to proceed northward; that, upon their return, fifteen days after, they told him, that they had been at the 89th degree of latitude, where they found no ice, but an open, deep sea, like that in the Bay of Biscay; and that they showed him the two ships journals in support of what they advanced. In fine, it is related in the Philosophical Transactions, that two navigators, who engaged in the discovery of this passage, penetrated 300 leagues to the east of Nova Zembla; but, on their arrival, the East India Company, who thought they had an interest in preventing the discovery, allowed them not to return that way to Europe*. But the Dutch East India Company, who believed themselves interested in the discovery, having made unsuccessful attempts on the European side, tried to find it by the way of Japan; and they would probably have succeeded, if the Emperor of China had not prohibited all strangers from navigating on the coasts of the lands of Jesso. This passage, there-

* See Collect. of Voyages to the North, p. 200.

fore, cannot be found but by steering directly to the pole beyond Spitzbergen, or rather by keeping the open sea between Nova Zembla and Spitzbergen, under the 79th degree of latitude. For the reasons already given, there is no occasion to dread ice, even under the pole itself; for there is no example of a large sea freezing at a great distance from land. The only sea that freezes totally is the Black Sea, which is narrow, contains little salt, and receives from the northern countries a number of rivers, and large boards of ice. If we may credit historians, this sea, in the time of the Emperor Copronymus, froze to the depth of 30 cubits. This may be an exaggeration: But that it freezes every winter is certain, while open seas, 1000 leagues nearer the pole, never do. This fact can only be explained by the superior saltiness, and the comparatively small quantity of ice-boards which these seas receive.

Boards of ice, which have been regarded as invincible obstacles to navigation near the poles, prove only the existence of large rivers in the neighbourhood of the places where they appear. They also demonstrate the existence of vast continents, from which these rivers derive their sources; and, therefore, we ought not to be discouraged by their appearance: Besides, very little reflection will convince us, that these boards of ice must be confined to particular places; that it is impossible they should occupy the whole circle in which the southern continent is

supposed to be contained; and, therefore, if a different route were taken, we have reason to hope for success. From the description of New Holland, given by Dampier, and others, it is probable, that this part of Terra Australis, which is, perhaps, a part of the southern continent, is a country less ancient than what remains to be discovered. New Holland lies low; it has neither mountains nor rivers; it is thinly inhabited, and the natives have no industry. All these circumstances induce us to think, that the savages of New Holland are similar to those of the Amazons, and of Paraguay, in America. In Peru and Mexico, which are the most elevated, and, of course, the most ancient countries of America, the manners of the inhabitants were polished; and they were divided into distinct nations, governed by sovereigns and by laws. Savages, on the contrary, are always found in low and new countries. Hence we may presume, that, in the elevated and interior parts of the southern continent, from which issue those large rivers that carry down boards of ice to the sea, there are men united by the bonds of society.

The interior parts of Africa are nearly as little known to us as they were to the ancients. They had circumnavigated this immense peninsula; but they have neither left us charts nor descriptions of its coasts. Pliny tells us, that this voyage was performed in the days of Alexander the Great; that the wrecks of some Spanish ships were

were found in the Arabian sea; and that Hanno, the Carthaginian General, had sailed from Gades to the Arabian gulf, and had written a relation of the voyage. He farther informs us, that, in the days of Cornelius Nepos, one Eudoxus, who had been persecuted by King Lathurus, was obliged to fly; that he departed from the Arabic gulf, and arrived at Gades; and that, previous to this period, Spain carried on a trade by sea with Æthiopia *. But, these testimonies notwithstanding, we are of opinion, that the ancients never doubled the Cape of Good Hope: Every man considered the voyage of the Portuguese to the East Indies as a new discovery. It will not be incurious to see the sentiments entertained of this subject in the ninth century. ‘ In our days, a discovery has been
 ‘ made which was totally unknown to those
 ‘ who lived before us. No man believed, or
 ‘ could suspect, that the sea which reaches from
 ‘ the Indies to China, had any communication
 ‘ with the sea of Syria. But we have lately
 ‘ found, according to my information, in the
 ‘ Mediterranean, or sea of *Roum*, the wreck of
 ‘ an Arabian ship which had been staved to
 ‘ pieces by a tempest. Some of these pieces had
 ‘ been carried, by the wind and the waves, into
 ‘ the sea of the Cozars; from thence round to
 ‘ the Mediterranean, and along that sea to the
 ‘ coast of Syria. This is a demonstration that the

* See Plin. Hist. Nat. tom. i. lib. 2.

‘ ocean furrounds China and Cila, the extremity
 ‘ of Turqueston, and the country of the Cozars,
 ‘ and that, at last, it enters by the Straits, and
 ‘ washes the borders of Syria. The evidence
 ‘ arises from the construction of the vessel ; for
 ‘ there are no ships but those of Siraf whose
 ‘ planks are not nailed. But the vessel above
 ‘ mentioned had all her planks stitched together
 ‘ in a manner peculiar to the Arabians. But
 ‘ all vessels belonging to the Mediterranean, and
 ‘ the coast of Syria, have their timbers fastened
 ‘ with nails *.’

I shall subjoin the remarks added by the translator of this ancient relation:

‘ Abuziel remarks, as a thing perfectly new,
 ‘ that a vessel had been carried from the Indian
 ‘ sea, and thrown upon the coast of Syria. To
 ‘ find a passage for it into the Mediterranean,
 ‘ he supposes, that there is a great extent of sea
 ‘ beyond China, which communicates with the
 ‘ sea of the Cozars, or of Muscovia. The sea
 ‘ beyond Cape Current was entirely unknown
 ‘ to the Arabians, on account of the extreme
 ‘ hazard of navigating it, and because the continent
 ‘ was inhabited by a people so barbarous,
 ‘ that it was impossible either to conquer them,
 ‘ or to civilize them by commerce. The Portuguese
 ‘ found not, from the Cape of Good
 ‘ Hope to Soffala, any Moors who had an esta-

* See *Les anciennes relations des voyages faits par terre a la Chine*, p. 53.

lished settlement, like those in all the maritime villages as far as China, which was the farthest place known to geographers. But they could not tell whether the Chinese sea communicated with that of Barbary by the extremity of Africa ; they only described it to the coast of Zinga or Caffraria. We cannot, therefore, hesitate in pronouncing, that the first discovery of the passage of this sea, by the Cape of Good Hope, was made by the Europeans, under the command of Vasco de Gama, or, at least, a few years before he doubled that Cape, if we may credit some sea-charts of an older date, where the Cape is marked under the name of *Fronteira da Africa*. Antony Galvan relates, upon the testimony of Francisco de Sousa Tavares, that, in 1528, the Infant Don Ferdinand shewed him a similar chart from the monastery of Acoboca, dated 120 years before, copied, perhaps, from that said to be in the treasury of St Marc at Venice, on which the point of Africa is likewise delineated, according to the evidence of Ramusio, &c.

The ignorance of these ages concerning the navigation round Africa is not, perhaps, so singular as the silence of the editor of this ancient relation with regard to the passages in Herodotus, Pliny, &c. which we have quoted, and which proved that the ancients had sailed round Africa.

However this matter stands, the coasts of Africa are now well known. But all the attempts which have been made to penetrate into the interior parts, have not furnished us with exact accounts. It would be a great object to go far up the country, by means of the Senegal, or some other great river, and establish settlements. According to every appearance, we should there find a country as rich in precious metals as Peru or Brasil. It is well known, that the rivers of Africa abound in gold dust; and, as the country is very high and mountainous, and is, besides, situated under the equator, it unquestionably contains, as well as America, mines of the heaviest metals, and stones of the hardest and most compact texture.

The vast extent of north and east Tartary is but a late discovery. If the Russian charts be just, we know the whole coast of this part of Asia; and it appears, that, from the termination of east Tartary to North America, it is an extent not above 400 or 500 leagues. It has even been lately reduced to a much shorter space. In the Amsterdam Gazette of 24th January 1747, under the article Petersburg, it is alleged, that M. Stollerravoit had discovered, beyond Kamtschatka, one of the North American isles, and that he had demonstrated that we might sail from Russia to America by a very short passage. The Jesuits and other missionaries also pretended to have known savages in Tartary, whom they had catechized in America, which supposes the passage
to

to be indeed very short *. Charlevoix would have us believe, that the old and new continents are united in the northern parts. He says, that some late voyages of the Japanese make it probable that the passage we have been mentioning is only a bay, beyond which we may pass, by land, from Asia to America. But this notion requires confirmation; for it has always been thought, that the continent of the North Pole is probably separated from all other continents, as well as that of the South Pole.

Astronomy and navigation have reached so high a pitch of perfection, that we may reasonably hope soon to have an exact knowledge of the whole surface of the globe. The ancients, who were ignorant of the mariner's compass, were able to discover a small part of it only. Some pretend that the Arabians invented this instrument, and that, by means of it, they carried on trade with India as far as China †. But this notion has always appeared to me to be destitute of foundation; for there is not in the Arabian, Turkish, or Persian languages, a word that signifies a mariner's compass: They use the Italian word *bussola*. Even at this moment, they can neither make compasses nor give polarity to the needle. They purchase these articles from the Europeans. Father Martini alleges, that the Chinese have been acquainted with the compass these

* See Charlevoix, tom. iii. p. 30.

† See l'Abregé de l'hist. des Sarazins de Bergeron, p. 119.

3000 years*. If these facts be true, how should it happen that they have made so little use of this instrument? Why, in their voyage to Cochinchina, did they take a longer course than was necessary? Why did they always limit themselves to the same expeditions, the longest of which was to Java and Sumatra? And why did they not discover, before the Europeans, a vast variety of islands and of fertile countries in their own neighbourhood, if they possessed the art of navigating in the open seas? It was but a few years after the discovery of this wonderful quality of the loadstone, that the Portuguese doubled the Cape of Good Hope, and traversed the African and Indian oceans, and that Christopher Columbus sailed to America.

It was not difficult to conjecture, that immense regions existed in the western part of the globe; for, on computing what was known of it, namely, the distance from Spain to China, and attending to the revolution of the earth, or of the heavens, it was easy to perceive, that a greater extent lay to the west than what had been already discovered on the east. That the ancients found not the new world, was not owing to a deficiency in astronomical science, but solely to their ignorance of the compass. The passages of Plato and of Aristotle, which mention countries far beyond the Pillars of Hercules, seem to indicate that some mariners had been driven by a tempest

* See hist. Sinica, p. 106.

on the coast of America, from which they had returned with infinite labour. But, supposing the ancients to have been thoroughly convinced, from the relations of voyagers, that such a continent existed, being ignorant of the compass, they could not possibly derive any advantage from such conviction.

I acknowledge, that it is not absolutely impossible for resolute men, with no other guide than the stars, to sail in open seas. The ancients were in possession of the Astrolabe. They might take their departure from France or Spain, and sail to the west by always keeping the polar star on their right hand; and, by frequent soundings, they might keep nearly in the same latitude. It was unquestionably by keeping the pole-star on their left, that the Carthaginians mentioned by Aristotle were enabled to return from those distant regions. But it will still be allowed, that a voyage of this kind must have been regarded as a rash and hazardous enterprize. We ought not, therefore, to be surpris'd, that the ancients never conceived such a project.

Before the expedition of Columbus, the Azores, the Canaries, and Madeira, had been discovered. It had been remarked, that, when the west winds continued long to blow, the sea threw upon the coasts of these islands pieces of strange wood, canes of an unknown species, and even dead bodies, which, by several marks, were known to be neither Europeans nor Africans*.

* See Charlevoix, tom. i. p. 66.

Columbus himself remarked, that, on the west coasts, certain winds blew for some days, which he was persuaded proceeded from land. But, though he possessed all these advantages over the ancients, and likewise the compass, the difficulties to be encountered were so great, that nothing less than success could have justified the enterprise. Suppose, for a moment, that the continent of America had been 1000 or 1500 leagues more distant, a circumstance which Columbus could not foresee, he never would have arrived, and perhaps this vast country might still have remained undiscovered. This conjecture receives additional force, when it is considered, that Columbus, though the ablest navigator of his age, was seized with terror and astonishment in his second voyage to the New World: As, in his first voyage, he found nothing but islands, he directed his course more to the south in quest of a continent; but found himself stopped by currents, the great extent of which, and their uniform opposition to his course, obliged him to direct his search more to the west. He imagined, that it was not currents which prevented him from advancing to the south, but that the sea was rising to the heavens, and that both perhaps touched each other in the southern parts: Thus, in great undertakings, the most trifling difficulty may sometimes turn a man's brain, and extinguish his courage.

P R O O F S
OF THE
THEORY OF THE EARTH.

A R T I C L E VII.

Of the Formation of Strata, or Beds, in the Earth.

WE have demonstrated, in the first article, that the earth, in consequence of the mutual attraction between the particles of matter, and of the centrifugal force that results from its diurnal revolution, must have assumed the figure of a spheroid, the two diameters of which differ about a 230th part; and that nothing but the changes made on the earth's surface, by the motions of the air and of the waters, could augment this difference, in the manner alleged by those who measured a degree under the equator, and another within the polar circle. This figure of the earth, which agrees so well with the laws of hydrostatics and with our theory, indi-
cates

cates that, at the time it assumed its figure, it was in a state of fluidity. We have also proved, that the projectile motion, and the motion of rotation, were impressed at the same time, and by the same impulse. It will more readily be admitted, that the earth was originally in a state of liquefaction, when it is considered, that the greatest part of the materials of which this globe is composed are either vitrifications, or vitrifiable by fire. The impossibility of rendering the earth fluid by the operation of waters confirms this hypothesis; because there is infinitely more earth than water, and the water is not able to dissolve sand, rocks, and hard minerals.

It is, therefore, evident, that the earth assumed its figure when in a fluid state: And, to pursue our theory, it is natural to think, that the earth, when it issued from the sun, had no other form but that of a torrent of melted and inflamed matter; that this torrent, by the mutual attraction of its parts, assumed a globular figure, which its diurnal motion changed into a spheroid; that, when the earth cooled, the vapours which were expanded like the tail of a comet, gradually condensed, fell down in the form of water upon the surface, depositing, at the same time, a slimy substance, mixed with sulphur and salts, part of which was carried, by the motion of the waters, into the perpendicular fissures of the strata, and produced metals, and the rest remained on the surface, and gave
rise

rife to the vegetable mould, which abounds, in different places, with more or lefs of animal and vegetable particles, whose organization is not obvious to the fenfes.

Thus the interior parts of the globe were originally compofed of vitrified matter; and, I believe, they continue fo at prefent. Above this vitrified matter were placed thofe bodies which the fire had reduced into the fmalleft particles; as fands, which are only portions of glafs; and, above thefe, pumice ftones, and the fcoriæ of melted matter, which gave rife to the different clays. The whole was covered with water to the depth of 500 or 600 feet*, which originated from the condensation of the vapours, when the earth began to cool. This water depofited a ftratum of mud, mixed with all thofe matters that are capable of being fublimed or exhaled by fire; and the air was formed of the moft fubtile vapours, which, from their levity, rofe above the water.

Such was the condition of the earth, when the tides, the winds, and the heat of the fun, began to introduce changes on its furface. The

* This opinion, that the earth was entirely covered with water, corresponds with the sentiments of feveral ancient philofophers, and likewife with thofe of many of the fathers of the church. In *mundi primordio, aqua in omnem terram stagnabat*, fays St. John of Damafcus, lib. 2. cap. 9. *Terra erat invisibilis, quia exundabat aqua et operiebat terram*; St. Ambrofe; lib. 1. cap. 8. *Submerfa tellus cum effet, faciem ejus, inundante aqua, non erat adfpectabilis*; St. Bafile, Hom. 2. See likewife St. Auguftine, lib. i. cap. 12.

diurnal motion of the earth, and that of the tides, elevated the waters in the equatorial regions, and necessarily transported thither great quantities of slime, clay, and sand, and, by thus elevating these parts of the earth, they perhaps sank those under the poles about two leagues, as was formerly remarked: For the waters would easily reduce into powder pumice-stones, and other spongy parts of the vitrified matter upon the surface, and, by this means, excavate some places, and elevate others, which, in time, would produce islands and continents, and all those inequalities on the surface, that are more considerable towards the equator than the poles. The highest mountains lie between the Tropics and the middle of the Temperate Zones, and the lowest from the polar circles towards the poles. Between the Tropics are the Cordeliers, most of the mountains of Mexico and the Brazils, the great and lesser Atlas, the mountains of the Moon, &c. Besides, both the land and the sea have most inequalities between the tropics, as is evident from the incredible number of islands peculiar to these regions.

However independent of my general theory, this hypothesis, concerning the original state of the globe, may be, I have chosen to refer to it in this article, with a view to show the connection and possibility of the system endeavoured to be established in the first article. It may only be remarked, that my theory is not opposed

ed by the facts; that I take the earth nearly as it stands at present; and that I lay hold of none of those suppositions which are often used in reasoning concerning the former condition of the earth. But, as I here offer a new idea upon this subject of the sediments deposited by the waters that, in my opinion, gave rise to the upper stratum of the earth, it will not be improper to exhibit the reasons upon which it is founded.

The vapours exhaled from the earth produce rain, dews, thunder, lightning, and other meteors. These vapours, therefore, are mixed with particles of water, air, sulphur, earth, &c.; and it is the solid earthy particles which constitute the slime or mud under consideration. The purest rain-water deposits a quantity of this mud; and, when a quantity of dew is collected, and allowed to corrupt, it produces a greater proportional quantity of mud, which is fat, unctuous, and of a reddish colour.

The upper stratum of the earth is composed of this mud, mixed with particles of animal and vegetable substances, or rather with particles of stone and sand. It is worthy of remark, that most arable land is reddish, and more or less blended with heterogeneous matters. The particles of stone or of sand found in the upper stratum, are of two kinds; the one is gross and heavy, the other fine, and sometimes impalpable. The gross is detached from the inferior stratum by labouring the ground; or, rather,

the upper stratum, by penetrating the inferior which is composed of sand or gravel, forms what is called *fat*, or *fertile sand*. The finer species proceeds from the air, falls down with the dew or rain, and intimately incorporates with the vegetable mould, or upper stratum. This last is nothing more than the dust, transported by the air, and again deposited by rain or a moist atmosphere. When the quantity of this mud is great in proportion to the particles of stone or sand, the soil is red and fertile; if it be considerably mixed with animal and vegetable substances, it is blackish; but if the quantity of mud and of vegetable and animal substances be small, the soil is white and barren; and even when the particles of sand, stone, or chalk, which compose these barren soils, are mixed with a considerable quantity of animal and vegetable substances, they become black and light, but have very little fertility. According, therefore, to the different proportions of these three ingredients, the soil is more or less fertile, and differently coloured.

In order to acquire distinct ideas concerning the strata of the earth, we shall take for an example the pits at Marly-la-Ville, which are exceedingly deep. This place is situated in a high, but flat and fertile country, and its strata lie horizontally. I procured specimens of all these strata in their order from M. Dalibard, an eminent botanist, and a man of science; and, after
having

having proved, with aqua fortis, the nature of the matters they respectively consist of, I arranged them in the following table.

Table of the different beds of earth at Marly-la-Ville, to the depth of 100 feet.

	Feet. Inch.	
1. A free reddish earth, mixed with a large quantity of mud, a little vitrifiable sand, and a greater proportion of calcinable sand, or gravel	13	
2. A free earth mixed with gravel and with more vitrifiable sand	2	6
3. Mud mixed with a large quantity of vitrifiable sand, which made but a small effervescence with aqua fortis	3	
4. Hard marl, which effervesced violently with aqua fortis	2	
5. A marly stone very hard	4	
6. Marl in powder, mixed with vitrifiable sand	5	
7. Fine vitrifiable sand	1	6
8. Marl resembling earth, mixed with a little vitrifiable sand	3	6
9. Hard marl, in which was found genuine flint	3	6
10. Gravel, or marl in powder	1	

Carried over . 39

		Feet.	Inch.
	Brought over	39	
11.	Eglantine, a hard ringing stone, of the grain of marble -	1	6
12.	Marly gravel -	1	6
13.	Marl in the form of hard stone, with a fine grain -	1	6
14.	Marl like stone, with a coarser grain - -	1	6
15.	Marl still more gross -	2	6
16.	Fine vitrifiable sand, mixed with fossil sea-shells, which had no cohesion with the sand, and which still preserve their natural colours	1	6
17.	Fine gravel, or marl-duft -	2	
18.	Marl in the form of a hard stone	3	6
19.	Marl in the form of coarse powder	1	6
20.	Hard stone, calcinable like marble	1	
21.	A gray vitrifiable sand, mixed with fossil shells, particularly with oysters and spondyles, which had no cohesion with the sand, and were not petrified - -	3	
22.	A white vitrifiable sand, mixed with the same shells -	2	
23.	A vitrifiable sand with red and white streaks, and mixed with the same shells	1	
24.	A coarser vitrifiable sand, mixed with the same shells -	1	

Carried over 64

		Feet. Inch.
	Brought over	64
25.	A fine, gray, vitrifiable sand, mixed with the same shells -	8 6
26.	A fine unctuous sand, with very few shells - -	3
27.	Brown free stone - -	3
28.	Vitrifiable sand, striped with red and white - -	4
29.	A white vitrifiable sand -	3 6
30.	A reddish vitrifiable sand -	15
Total depth of the pit		101

I formerly mentioned, that I had examined all these substances with aqua fortis, because no other test can enable us to make real distinctions between earthy bodies of the same or of different appearances. Those which effervesce and suddenly dissolve, on the application of the aqua fortis, are generally calcinable. Those, on the other hand, upon which that acid makes no impression, are vitrifiable.

From this enumeration of strata it is evident, that the land at Mary-la-Ville was formerly covered with the sea, to the depth of 75 feet, since shells are found 75 feet below the surface. Those shells have been collected and deposited by the water, together with the sand, which contains them; and the whole superior strata, except the uppermost, have been transported
L 3 thither

thither by the motion of the waters, and deposited in the form of sediment, as is apparent from their horizontal position, from the mixture of sand, shells, and marl, which last is composed of decayed shells; and even the upper stratum has been almost wholly formed of slime or mud, with a small mixture of marl.

I have chosen this example, because it is least favourable to my theory; for it appears, at first view, difficult to conceive how the mud deposited by the dew and rains should produce a bed of vegetable soil 13 feet thick. But it ought to be remarked, that a soil of this thickness is rarely to be found, especially in high countries. The general run of soils are from three to four feet, and often they exceed not one foot. The soil is thickest in plains surrounded with hills; because the rains daily bring fresh supplies from the higher grounds. But, abstracting from this supposition, it is plain, that the upper strata formed by the sea are thick beds of marl. It is natural to think, that the upper stratum was originally much thicker, and that, beside the 13 feet, the sea would leave a considerable quantity of marl. But this marl, being exposed to the action of the air, of rains, and of the rays of the sun, would soon be reduced into a fine powder. The sea would not leave this land suddenly, but would continue for some time occasionally to cover it, either by the motion of the tides, or by extraordinary

dinary swells during great storms; and, of course, the upper stratum would be mixed with mud, clay, and other slimy bodies. After being entirely above the reach of the waves, plants would begin to grow, and the soil would constantly accumulate, and be tinged with a reddish colour by the mud deposited by dews and rain. Culture would still farther increase both its fertility and its thickness, and, by allowing the dews and rains to penetrate deeper, would in process of time produce this soil of 13 feet.

I shall not here examine, whether the reddish colour of vegetable mould proceeds from a quantity of iron contained in the mud deposited by rain and dews. This point, which is of some importance, shall be discussed when we come to treat of minerals. It is sufficient to have given a view of the manner in which the upper stratum has been formed: We shall now prove, by other examples, that the formation of the interior strata of the earth must likewise have originated from the operation of the waters.

The upper stratum of the globe, says Woodward, that magazine for the formation and support of animals and vegetables, is mostly composed of vegetable and animal matter, and is in perpetual fluctuation. All the animals and vegetables which have existed since the creation, have successively extracted from this stratum the materials of which their bodies are constructed; these they again restore at their dissolution, where

they remain prepared for the successive formation of new bodies of the same species; the matter which forms one body being naturally disposed to make another of the same kind*. In uninhabited countries, where the woods are never cut, nor the herbs browsed by cattle, the soil is constantly augmenting. The soil, in all woods, even in those which are occasionally cut, is from 6 to 8 feet thick, and has originated from the leaves, and other decayed parts of vegetables. I have often remarked, that, upon an old Roman way which runs across Burgundy, the stones with which it was constructed are covered with a black mould of more than a foot thick, and that it nourishes trees of a considerable size. This soil could only be produced by the gradual and successive destruction of vegetable bodies. As vegetables derive more of their substance from the air and water than from the earth, when they decay, they add more to the soil than they extracted from it. Besides, forests collect and retain vapours and moisture; and, of course, in old woods, the soil is greatly augmented. But, as animals restore much less to the earth than they take from it; and, as men consume vast quantities of wood and herbs for fuel and other purposes, it follows, that the vegetable soil of populous countries must continually diminish, and become, in time, like those of Arabia Petrea and other eastern countries, which were first inhabited, where nothing is now

* See Woodward's Essay, p. 136.

to be found but sand and salts ; for the fixed salts of plants and of animals remain, while all the other parts volatilize, and are carried off by the air.

Let us next examine the position and formation of the interior strata. The earth, says Woodward, wherever it has been dug, is composed of beds or strata, one above another, in the same manner as if they had proceeded from successive sediments deposited by water. The beds which lie deepest are thicker than those immediately above them, and they are gradually thinner till they arrive at the surface. Sea-shells, teeth, and bones of fishes, are found in these beds, and not only in those which are soft, as chalk, clay, and marl, but even in beds of hard stone, marble, &c. These productions of the sea are incorporated with the stone, and, when separated, leave in the stone the figure of their surface exactly delineated. ‘ I was abundantly assured,’ says this author, ‘ that the circumstances of these things in remoter countries were much the same with those of ours here: That the stone, and other terrestrial matter, in France, Flanders, Holland, Spain, Italy, Germany, Denmark, Norway, and Sweden, was distinguished into strata, or layers, as it is in England: That those strata were divided by parallel fissures: That there were inclosed in the stone, and all the other denser kinds of terrestrial matter, great numbers of shells, and
‘ other

‘ other productions of the sea; in the same manner as in that of this island. To be short, by the same means I got sufficient intelligence that these things were found in like manner in Barbary, in Egypt, in Guiney, and other parts of Africa: In Arabia, Syria, Persia, Malabar, China, and other Asiatic provinces: In Jamaica, Barbadoes, Virginia, New England, Brasil, Peru, and other parts of America.’
p. 6. 41, 42, &c.

Woodward gives no authority for his assertion, that shells are found in the strata of Peru. But as, in general, his facts are true, I doubt not but his information has been good; and I am persuaded that shells exist in the strata of Peru, as well as every where else. I make this remark on account of a doubt which has been entertained, and which shall afterwards be considered.

In digging a well at Amsterdam, 232 feet deep, the strata were arranged in the following order: 7 feet of vegetable soil; 9 feet of turf; 9 feet of soft clay; 8 feet of sand; 4 of earth; 10 of clay; 4 of earth; 10 of sand; 2 of clay; 4 of small white sand; 5 of dry earth; 1 of soft earth; 14 of sand; 8 of clay mixed with sand; 4 of sand mixed with shells; then 102 feet of clay; and, *lastly*, 31 feet of sand*.

It is uncommon to dig so deep before we find water: But this fact is remarkable in

* See Varenii Geograph. gen. p. 46.

many

many other respects. 1st, It demonstrates that the sea communicates not with the interior parts of the earth by means of filtration: 2^d, That shells are found 100 feet below the surface in a country extremely low; and, consequently, that the land of Holland has been elevated 100 feet by the sediments of the ocean: 3^d, It may be concluded, that the bed of clay of 102 feet, and the bed of sand, 31 feet of which only had been dug, and whose actual thickness is unknown, lie near to the ancient and original earth that existed before the motion of the waters began to change its surface. In the first article, it was remarked, that, in order to discover the ancient earth, we must dig in the northern, rather than in the southern regions; and in the low and plain, rather than in the elevated countries. These circumstances nearly concurred in the present case. We only wish that the pit had been dug deeper, and that the author had informed us, whether shells, or other sea-bodies, were intermixed with the last strata of clay and of sand. This experiment confirms what was formerly advanced, that the strata are always thicker in proportion to their depth.

The earth consists of parallel and horizontal strata, not in the plains only, but, in general, the hills and mountains have the same structure. The strata of the mountains are even more conspicuous than those of the plains; for the plains are commonly covered with great quantities of sand

sand and earth brought from the higher grounds by the waters; and, therefore, to find the ancient strata, we must dig deeper in the plains than in the mountains.

I have often remarked, that, when the top of a mountain is level, its strata are likewise level; but, when the top is not horizontal, the strata follow the direction of its declivity. It has frequently been alleged, that the beds of quarries incline to the east. But in all the chains of rocks which I have examined, I found, that these beds always follow the declivity of the hill, whether its direction be east, west, south, or north. In raising stones from the quarry, they are always separated according to their natural position; and, if cut in a contrary direction, it is impossible to raise them of any considerable size. In all good masonry, the workmen place the stones in the direction in which they lay in the quarry. If laid in an opposite position, they will split, and be unable to resist the weight of the incumbent building. Hence we may conclude, that stones have been originally formed in horizontal beds; that these beds have been successively accumulated above each other, and have been composed of materials, the resistance of which is stronger in that than in any other direction.

Every stratum, of whatever kind, whether it be horizontal or inclined, is of an equal thickness through its whole extent. In the quarries round Paris, the stratum of good stone is but
about

about 18 or 20 inches thick throughout. In the quarries of Burgundy, the stone is much thicker. The same inequalities take place in marbles. The white and black marbles are thicker than those that are coloured; and there is a hard stone with which the people of Burgundy cover their houses, that exceeds not an inch in thickness. Thus, different strata differ much with regard to thickness; but each stratum uniformly preserves the same thickness through its whole extent. This difference is so great, that strata are to be found, from less than a line, to 1, 10, 20, 30, and 100 feet thick. Both ancient and modern quarries, which are dug horizontally, the shafts of mines, and the working of lead, either longitudinally or transversely, prove that strata extend a great way on all sides. 'It is well known,' as the historian of the academy observes, 'that
 ' all stones have originally been a soft paste, and
 ' that, as stones are almost every where to be
 ' met with, the surface of the earth, in all these
 ' places, at least to a certain depth, must have
 ' consisted of mud and slime. The shells found
 ' in most quarries demonstrate, that this mud
 ' was an earth diluted by the water of the sea;
 ' and, consequently, that the sea once covered
 ' all these places; but the sea could not cover
 ' them, without, at the same time, covering all
 ' places that were lower, or on the same level.
 ' Now, it is impossible that the sea could cover
 ' all those places where there are quarries, with-
 ' out

‘ out covering the whole surface of the globe.
 ‘ If the mountains were then formed, the sea
 ‘ must also have covered them; for they are full
 ‘ of rocks and quarries, and shells are often
 ‘ found in them.

‘ The sea, then,’ continues he, ‘ covered the
 ‘ whole earth; and hence all the beds of stone
 ‘ in the plains are horizontal and parallel: The
 ‘ fishes, therefore, were the most ancient inha-
 ‘ bitants of the globe; for neither land-animals
 ‘ nor birds could exist. But how has the sea
 ‘ retired into those vast basins which it now oc-
 ‘ cupies? The most natural supposition is, that
 ‘ the earth, at least to a certain depth, was not
 ‘ all equally solid, but interspersed with vast
 ‘ vaults or caverns, the arches of which would
 ‘ remain for a time, and at last suddenly fall in.
 ‘ The waters would then rush into these hollows,
 ‘ fill them up, and leave a part of the surface
 ‘ dry, which would become a convenient habi-
 ‘ tation for land-animals and birds. The shells
 ‘ found in quarries strongly confirm this idea;
 ‘ for nothing but the bony parts of fishes could
 ‘ be preserved so long in the earth. Besides,
 ‘ shells commonly lie in vast masses in certain
 ‘ parts of the sea, where they remain immove-
 ‘ able, and form a species of rocks or banks;
 ‘ they could not, therefore, follow the sea, which
 ‘ suddenly abandoned them. It is for this last
 ‘ reason that we find such numbers of fossil-
 ‘ shells, and so few vestiges of other fishes, which

* is a farther proof that the waters retired with
 * rapidity into their present basons. When the
 * vaults sunk down, it is very probable that
 * mountains were elevated by the same cause,
 * and placed upon the surface with rocks and
 * quarries already formed. But the beds of these
 * quarries could not preserve their original ho-
 * rizontal position, unless they were raised exact-
 * ly perpendicular to the surface, which would
 * rarely happen. Thus, as we formerly remark-
 * ed *, the beds of stone in mountains are all
 * inclined to the horizon, though they be paral-
 * lel to each other ; for they changed not their
 * position with regard to one another, but with
 * regard only to the surface of the earth †.

These parallel beds of earth or of stone, which
 have been formed by sediments of the ocean,
 often extend to considerable distances. We even
 find, in hills separated by valleys, beds of the
 same materials upon equal levels. This obser-
 vation has a perfect correspondence with the
 equal altitudes of opposite hills. The truth of
 this fact may be easily established ; for, in all
 hills separated by narrow valleys, where stone
 or marble is found on one hill, we uniformly
 find these very substances, at the same level, on
 the opposite hill. I have traced a quarry of
 marble 12 leagues in length ; its breadth is also
 considerable, though I have not been able to as-
 certain it with precision. I have often observed,

* See Mem. de l'Acad. ann. 1705, p. 36.

† Ibid. ann. 1716, p. 14.

that this bed of marble has every where the same thickness; and that, in hills separated by a valley of 100 feet deep, the same bed always appeared at the same altitude. I am firmly persuaded, that this observation holds with regard to all quarries of stone or of marble which contain shells; but it applies not to beds of free-stone. We shall afterwards explain why free-stone is not dispersed, like other matters, in horizontal beds, but in blocks, irregular both in form and position.

It has likewise been remarked, that, on the opposite sides of straits of the sea, the strata are the same. This observation is important, and may lead to the discovery of those necks of land, or islands, which have been separated from the Continent. It proves, for example, that England has been separated from France, Spain from Africa, and Sicily from Italy: And it is to be regretted, that the same observation has not been made upon all straits. I have no doubt but it will hold universally. We know not, whether, in the straits of Magellan, the longest we are acquainted with, the same strata are to be found at the same latitude. But we perceive, from very exact charts, that the opposite coasts, which are high, have corresponding angles like those observable in our inland mountains; and this further proves Terra del Fuego to have been formerly a part of the Continent of America. The same remark has been made with regard to the
 strait

strait of Frobisher; and the island of Friesland appears to have been separated from the continent of Greenland.

The Maldivia islands are separated from each other by small branches of the sea; and, on each side of the opposite islands, the strata of rocks, &c. are the same. These islands, which, when taken together, extend about 200 leagues in length, were formerly one. They are divided into 13 provinces, called *Clusters*. Every Cluster contains a great number of small islands, most of which will soon be under water. It is remarkable, that each of these 13 Clusters is surrounded with a chain of rocks of the same stone, and that there are only three or four small and dangerous openings, through which each of them can be approached. They are all placed in a line, with their ends to each other, and appear evidently to have been once a long mountain crowned with rock*.

Several authors, as Verstegan, Twine, Sommer, but particularly Campbell, in his description of the county of Kent, give striking proofs that England was formerly joined to France, and that the neck of land that divides them had been carried off by the sea, which retired, and left a great quantity of low marshy ground along the southern coasts of England. As a farther proof of this fact, Dr. Wallis has attempted to show an affinity between the an-

* See *Voyag. de Franc. Pyrrard*, vol. i. p. 107.

cient language of the Gauls and that of the Britains ; and he adds several other remarks, which shall be related in the following articles.

If travellers observed the figure of lands, the position of mountains, and the windings of rivers, they would perceive that opposite hills are not only composed of the same materials at the same altitudes, but that they are also nearly of an equal height. In all the places where I have travelled, I uniformly remarked this equality in the height of opposite hills, especially when they are separated by valleys not above a fourth or a third of a league wide. In valleys of greater width, it is difficult to judge of the height or equality of hills ; for, on looking over a level and extensive plain, it appears to rise ; and distant hills seem to sink. But this is not the place to account for these phænomena. Besides, it is not easy to determine by the eye the middle of a large valley, unless it be traversed by a river. But, in narrow valleys, the judgment of the eye is more certain. That district of Burgundy comprehended between Auxerre, Dijon, Autun, and Bar-sur-seine, of which a considerable portion is called *le Bailliage de la Montagne*, is one of the most elevated parts of France. From one side of these mountains, which are only of the second order, the water runs to the ocean, and from the other, to the Mediterranean. There are points of partition, as at Sombornon, Pouilli in Auxois, &c. where the

the water may be turned at pleasure, either to the ocean or the Mediterranean. This high country is intersected with a number of small valleys, and most of them are watered with rivulets. Here I have a thousand times observed the corresponding angles of the hills, and their equality as to height; and I can with confidence affirm, that the salient or prominent angles are uniformly opposed to the concave ones, and that the heights of the two sides are nearly the same. The farther we advance in this high country, where are the points of partition mentioned above, the mountains rise the higher. But this height is always the same on the opposite sides of the valleys, and the hills rise or fall equally. The same observation I have repeatedly made in several other provinces of France; but they extend not to very high mountains; for these are more irregular as to height, and often terminate in unequal points or peaks. In frequently traversing the Alps and Appennines, I observed, that the angles, in effect, corresponded; but that it is almost impossible to judge, by the eye, concerning the equality or inequality in the heights of opposite mountains; because their tops are lost in the clouds.

The different strata composing the earth are not arranged according to their specific gravities. Beds of heavy matter are frequently placed above those of lighter. Solid rocks are often supported by beds of earth, clay, or sand, which

are greatly inferior in specific gravity. This is the case with most hills, and is easily perceived. But, in high mountains, the summits are not only rocks, but these rocks are supported by others; and this structure runs through such an extent of country, where one mountain rises out of another, that it is difficult to determine whether they are founded on earth, or of what nature this earth is. I have seen rocks cut perpendicularly for some hundreds of feet; but these rocks rested upon other rocks, without my being able to perceive where they ended. May we not, however, be allowed to conclude from the less to the greater? Since the rocks of small mountains, the bases of which are visible, rest upon earths less heavy and less solid than stone, is it not reasonable to think, that earth is likewise the basis of high mountains? Besides, all I have here advanced tends to prove, that heavy bodies might be accumulated, by the motion of the waters, above light ones; and, if this really takes place in most hills, it is probable that it has happened in the manner pointed out by my theory. But, should it be objected, that I had no reason to suppose, that, prior to the formation of mountains, the heavier matter was below the lighter; I answer, that I affirm nothing with regard to this article; because there are many ways by which this effect might be produced, whether the heavy matter was above or below, or placed indifferently: For, in order to
conceive

conceive how the sea could first form a mountain of clay, and then crown it with rocks, we have only to consider, that the sediments might be transported from different places, and that they might consist of different materials. The sea might transport from one place several sediments of clay, and afterwards deposit sediments of stony matter ; either because all the clay at the bottom, or on the coasts, was exhausted, and then the waves would attack the rocks ; or, rather, because the first sediments were transported from one place, and the last from a different one. Besides, the latter corresponds exactly with experience ; for, it is a known fact, that beds of earth, stone, gravel, sand, &c. follow no rule of arrangement, but are placed indifferently, and, as it were, by chance, one above another.

This chance, however, ought to have some rules, which can only be discovered by analogy and probable conjecture. We have seen, that, according to my theory of the formation of the globe, its interior parts should consist of vitrified matter, similar to vitrified sand, which is only the fragments of glass, and of which the clays are the scorixæ, or decomposed parts. Agreeable to this supposition, the centre of the earth, and even near the surface itself, should be composed of glass or vitrified matter, and above this should be found sand, clay, and other scorixæ. Thus, the earth, in its original state,

was a nucleus of glass, or of vitrified matter, either compact like glass, or divided like sand, (for that circumstance depends on the degree of heat applied); above this matter was sand; and, lastly, clay. The soil, or external covering, was produced from the air, and the mud of water; and it is more or less thick according to the situation of the ground; more or less coloured, according to the different mixtures of mud, sand, clay, and the parts of decayed animals and vegetables; and more or less fertile, according to the abundance or deficiency of these parts. To show that this account of the formation of sand and clay is not altogether imaginary, I shall add a few remarks.

I suppose the earth, in its first state, to have been a spheroid of compact glass, covered with a thin crust of pumice-stone, and other scorixæ of melted matter. The agitation of the air and of the water would soon reduce this crust of pumice into powder or sand, which, by uniting into masses, would give rise to free-stone and flints, the varieties of which, with regard to colour and density, depend upon the different degrees of fineness of the sand that composed them.

The constituent parts of sand unite by the application of fire, become very hard, compact, and more or less transparent, according to the purity of the sand. But, on the other hand, when exposed to the action of the air, it exfoliates,

liates, falls down in the form of earth, and may thus produce clays of different kinds. This dust, which is sometimes yellow, sometimes brilliant, and is used to dry writings, is nothing else than a fine sand, somewhat corrupted, and nearly reduced to an elementary state. Its particles, in time, become so attenuated and divided, that they lose the power of reflecting light, and acquire all the properties of clay. On examining a piece of clay, many of these shining or talky particles appear; because they have not yet entirely lost their original form. Sand, therefore, in process of time, may produce clay; and this clay, by a farther division, acquires the qualities of mud or slime, a vitrifiable matter of the same nature with clay.

This theory is confirmed by daily experience. In washing sand, the water becomes impregnated with a black, soft, fatty earth, which is a genuine clay. The mud swept from streets paved with free-stone, is black and very fat, and, when dried, it discovers itself to be an earth of the same nature with clay. Clay, taken from places where there is neither flint nor free-stone, and diluted with water, always precipitates a great quantity of vitrifiable sand.

But, what clearly demonstrates the existence of sand, and even of flint and glass, in clay, is, that the re-union of its parts, by the action of fire, restores it to its original form. Clay, when heated to the degree of calcination, is covered

with a hard coat of enamel ; if its internal parts are not vitrified, they become so extremely hard as to resist the file ; they strike fire with the hammer, and acquire all the properties of flint : A great degree of heat melts and converts them into real glass.

Clay and sand, therefore, are substances perfectly analogous, and of the same kind. If clay can be condensed to flint, and even to glass, why may not sand, by resolution, become clay ? Glass appears to be the true elementary earth, and all mixed bodies are only glass in disguise. Metals, minerals, salts, &c. are only a vitrifiable earth : Common stone, and other analogous bodies, testaceous and crustaceous shells, &c. are the only substances which cannot be vitrified, and which seem to form a distinct class. The former, by the action of fire, may be converted into a homogeneous, hard, and transparent substance, without any diminution of its weight, and upon which no farther change can be made. The latter, on the contrary, which consist of more active and volatile principles, calcine in the fire, lose more than a third of their weight, and resume the form of simple earth, without any other change than the resolution of their constituent parts. If these bodies be excepted, which are few in number, and of which the combinations produce few varieties in nature, all other substances, and particularly clay, may be converted into glass, and, consequently, are only

only glass in a decomposed state. If fire quickly vitrifies these substances, glass itself, whether simple, or in the form of sand or flint, naturally, but by a slow and insensible progress, resolves into clay.

In countries where flint is the predominant stone, the fields are commonly strewed with its fragments: If the place be uncultivated, and if the flints have remained long exposed to the air without being moved, their upper surface is always white; but the surface next the ground preserves its natural colour, which is very brown. When these flints are broken, the whiteness appears to be not superficial only, but penetrates more or less into their internal parts, and forms a belt, which in some is not very deep, but, in others occupies nearly the whole stone. This white part is somewhat granulated, perfectly opaque, as tender as free-stone, and adheres to the tongue like the boles. But the other portion of the flint is smooth and polished, has neither thread nor grain, and preserves its original colour, its transparency, and its hardness. When this half decomposed flint is put into a furnace, the white part becomes red like a brick, and the brown part becomes exceedingly white. Why shall we conclude, with a famous naturalist, that flints of this kind are imperfect, and that they are not old enough to have acquired their perfect state? For why should they be all imperfect? And why should they be uniformly imperfect

imperfect on the side only that is exposed to the air? It is, on the contrary, much more probable, that they are changed from the original state, and partly decomposed, and that they are gradually resolved into clay or bole. If this reasoning should appear to be unsatisfactory, expose to the air the hardest and blackest flint, in less than a year the colour of its surface will be changed; and, if the experiment be farther prosecuted, the flint will be found gradually to lose its hardness, its transparency, and its other specific characters, and make daily approaches to the nature of clay.

Sand undergoes the same changes as flint. Every grain of sand may, perhaps, be considered as a small flint, and every piece of flint as a collection of fine sand cemented together. The first example of the decomposition of sand is exhibited in that shining, but opaque powder, called *mica*, with which clay and slate are always impregnated. The quartz, or perfectly transparent flints, in decomposing, produce fat and soft talcs, such as those of Venice and Russia, which are as ductile and vitrifiable as clay; and it appears, that talc is the mean between glass, or transparent flint, and clay; but that the gross and impure flints, in decomposing, are converted into clay without any intermediate state.

Our made glass undergoes the same change; when long exposed to the air, it decomposes, and, as it were, ~~corrupts~~ ^{effluvescens}. At first, it assumes a
number

number of colours, then it exfoliates, and, in handling it, we perceive that many shining particles fall off. But, when its decomposition is farther advanced, it bruises between the fingers, and is reduced to a very white, talky, and impalpable powder. Art also imitates nature in the decomposition of glass and flint. ‘Est etiam
 ‘ certa methodus, solius aquæ communis ope,
 ‘ filices et arenam in liquorem viscosum, eun-
 ‘ demque in sal viride convertendi, et hoc in ole-
 ‘ um rubicundum, &c. Solius ignis et aquæ
 ‘ ope, speciali experimento, durissimos quosque
 ‘ lapides in mucorem resolvo, qui distillans sub-
 ‘ tilem spiritum exhibet, et oleum nullis laudi-
 ‘ bus prædicabile*.’

These matters shall be more fully considered when we treat of metals. We shall here only add, that the different strata of the globe consist either of materials which may be considered as actual vitrifications, or analogous to glass, and possessing its most essential qualities. It is also evident, that, from the decomposition of glass and flint, which daily takes place, there results a genuine clay. Hence we may conclude, with a high degree of probability, that sand and clays have originally been the scorixæ of burnt matter, especially when we join to the above circumstances, the proofs *a priori* which have been employed to show that the earth was formerly in a state of liquefaction occasioned by the operation of fire.

* Vid. Becher. Phys. Subterr.

P R O O F S

OF THE

THEORY OF THE EARTH.

A R T I C L E VIII.

Of Shells, and other productions of the Sea, found in the Interior Parts of the Earth.

I Have often examined quarries, the stones of which were full of shells. I have seen whole hills composed of shells, and chains of rocks intermixed with shells through their whole extent. The quantity of shells, and other productions of the sea, is, in many places, so prodigious, that it is difficult to believe any more of them existed in their natural element. It is from this enormous quantity that no doubt remains of the earth's having continued for a very long time under the waters of the sea. The number of sea-shells found in a fossil or petrified state is so amazing, that were it not for this

this circumstance, we never should have had a proper idea of the surprising quantities of those animals to which the ocean gives birth. We must not, therefore, imagine, like those who talk and reason concerning things they never saw, that shells are only to be found scattered here and there by chance, or in small heaps, like those of oysters thrown from our doors. They appear, on the contrary, in masses like mountains, in banks of 100 or 200 leagues in length. They may often be traced through whole provinces, and in masses of 50 or 60 feet thick. It is only after having learned these facts that a man is entitled to reason on this subject.

The shells of Turenne may serve as a striking example. Let us attend to the description given of them by the historian of the Academy*.

‘ Though figured stones, and even fossil shells
 ‘ found in the bowels of the earth were remark-
 ‘ ed in all ages and nations, they were generally
 ‘ considered, even by philosophers, as *lufus na-*
 ‘ *turæ*; the production of them was ascribed
 ‘ to chance, or to some unaccountable and for-
 ‘ tuitous train of circumstances; and, of course,
 ‘ this wonderful phenomenon added nothing
 ‘ to the stock of knowledge. An ignorant pot-
 ‘ ter in Paris†, who knew neither Greek nor
 ‘ Latin, about the end of the 16th century, was
 ‘ the

* Année 1720, p. 5.

† The correspondence of Palissy's ideas with those of the ancients, is worth remarking. ‘ *Conchulus, arenas, buccinas,*
 ‘ *calculos*

' the first man who ventured, in opposition to
 ' all the learned, to affirm, that fossil shells were
 ' real shells originally deposited by the sea, in
 ' those places where they are found; that real
 ' animals, and particularly fishes, bestowed on fi-
 ' gured stones their various forms, &c. and he
 ' boldly defied the whole school of Aristotle to
 ' invalidate his proofs. His name was Bernard
 ' Palissy; and he was perhaps the most conspi-
 ' cuous example of a philosophical genius, un-
 ' improved by art or learning. His system,
 ' however, has lain dormant for near a century,
 ' and even his name has almost been forgot.
 ' At last, several philosophers revived Palissy's
 ' ideas; and science has derived great advantage
 ' from all the fossil shells and figured stones
 ' which have appeared in the earth: They are
 ' now, perhaps, become too common, and the
 ' consequences drawn from them too incon-
 ' testible.

' But Reaumur's late observations on the sub-
 ' ject are astonishing. He discovered a mass
 ' below ground of 130,680,000 cubic fathoms
 ' of shells, either whole or in fragments, with-
 ' out the least mixture of stone, earth, sand, or
 ' other foreign matter. Before this remarkable
 ' instance, fossil shells never appeared in such
 ' enormous quantities, nor without being mixed

' calculos varie infectos, frequenti solo, quibusdam etiam in mon-
 ' tibus reperiri, certum signum maris alluvione eos coopertos
 ' locos volunt Herodotus, Plato, Strabo, Seneca, Tertullianus,
 ' Plutarchus, Ovidius, et alii; Vide Dausqui, Terra et aqua, p. 7.

' with

' with other bodies. This prodigious mass lies
 ' in Turenne, more than 36 leagues from the
 ' sea. It is of great service to the peasants of
 ' that province; they use the shells for marl in
 ' fertilizing their lands, which would otherwise
 ' be perfectly barren.

' What the peasants dig out of the earth, to
 ' the depth of eight or nine feet, consists only
 ' of fragments of shells; but these fragments are
 ' easily recognised to be those of real shells; for
 ' they still retain their original channels or fur-
 ' rows, and have only lost their lustre and var-
 ' nish, as most shells do, after having remained
 ' long under ground. The smallest fragments
 ' are only dust; but we know them to be the
 ' dust of shells, because they consist of the very
 ' same matter with the larger fragments, and
 ' the entire shells, which are sometimes found.
 ' The species both of the large fragments and
 ' of the entire shells, are easily distinguishable.
 ' Some of these species belong to the coast of
 ' Poitou, and others of them to foreign shores.
 ' This mass likewise furnishes corals, and other
 ' productions of the sea. *Falun* is the name by
 ' which this matter is distinguished in that pro-
 ' vince; and it is found, wherever the ground
 ' is dug, through an extent of about nine leagues
 ' square. The peasants never dig deeper than
 ' about 20 feet; because, says Reaumur, they
 ' imagine that the expence of labour would ex-
 ' ceed the value of the commodity. They might,
 ' however,

‘ however, dig deeper. But our calculation of
 ‘ 130,680,000 cubic fathoms proceeds upon the
 ‘ supposition of only 18 feet deep, and 2200
 ‘ fathoms to the league. Every article, there-
 ‘ fore, is undervalued, and this mass of shells
 ‘ must greatly exceed the above calculation; if
 ‘ the quantity be only doubled, this wonderful
 ‘ phænomenon will be greatly augmented.

‘ In physical facts, there are little circum-
 ‘ stances, often overlooked by the bulk of man-
 ‘ kind, which are, notwithstanding, of great
 ‘ consequence in illustrating the subject. M. de
 ‘ Reaumur has remarked, that all the fragments
 ‘ of shells lie horizontally in the great mass; from
 ‘ which he concludes, that the fragments were
 ‘ not deposited at the same time with the entire
 ‘ shells which originally formed this mass; be-
 ‘ cause, says he, the superior shells would, by
 ‘ their weight, have broken the inferior ones,
 ‘ and the fragments, in that case, would neces-
 ‘ sarily have been disposed in a thousand differ-
 ‘ ent directions. The whole, therefore, whether
 ‘ entire or broken, must have been gradually
 ‘ transported thither by the sea, and, of course,
 ‘ their position must have been horizontal. But,
 ‘ though time alone was sufficient to break them
 ‘ down, and even to calcine them, it could not
 ‘ vary their original position. Their transport-
 ‘ ation must have been gradual; for, it is im-
 ‘ possible that such an immense number of shells
 ‘ could be suddenly crowded together, and yet
 ‘ preserve

‘ preserve a position uniformly horizontal ; and
 ‘ their being assembled in one place, demonstrates
 ‘ this place to have once been the bottom of a
 ‘ gulf or bafon.

‘ Though there are many vestiges of the uni-
 ‘ versal deluge which is recorded in scripture, yet
 ‘ the mass of shells at Turenne could not be an ef-
 ‘ fect of this deluge. Perhaps such an amazing
 ‘ mass is no where to be found, even in the bot-
 ‘ tom of the sea. But, supposing the deluge to
 ‘ have forced such a quantity from the ocean,
 ‘ they would necessarily be carried off with vio-
 ‘ lence and precipitation ; and, consequently,
 ‘ could never have been deposited in the same
 ‘ position. They must have been transported,
 ‘ slowly floating in the waves ; and, of course,
 ‘ their accumulation would require a much
 ‘ longer time than a year.

‘ Upon the whole, it is plain, that, either be-
 ‘ fore or after the deluge, the earth, at least some
 ‘ parts of it, must have been in a very different
 ‘ situation from what it now appears ; that the
 ‘ sea and land must have had a different arrange-
 ‘ ment ; and that there was formerly a great
 ‘ gulf in the middle of Turenne. The changes
 ‘ recorded in history, or even in ancient fable,
 ‘ are inconsiderable ; but they give us some idea
 ‘ of what might be produced in a long series of
 ‘ ages. M. de Reaumur conjectures, that Tu-
 ‘ renne was formerly a gulf of the sea, and that
 ‘ the shells were transported by a current. But

‘ this is only a mere conjecture, thrown out to
 ‘ supply the place of a fact as yet imperfectly
 ‘ known. Before any certain conclusion can
 ‘ be drawn, we must have geographical charts of
 ‘ all those places where shells are found below
 ‘ the surface of the earth. To accomplish this,
 ‘ much time and numberless observations are
 ‘ requisite. Science, however, may in time be
 ‘ carried thus far.’

An attention to the following circumstances will lessen our surprise at this great collection of shells: 1. Shell-fish multiply prodigiously, and arrive at maturity in a very short time. The multitude of individuals in every species is a demonstration of their amazing fertility. In a single day, for example, a mass of oysters, of several fathoms in thickness, is often raised; the rocks to which they are attached, diminish considerably in a short time; and some banks are entirely exhausted. The following year, however, furnishes an equal quantity, and not the smallest diminution appears. It is even doubted, whether a natural bed of oysters was ever entirely exhausted. 2. The substance of shells is analogous to that of stone; they are long preserved when immersed in soft matter; and they easily petrify when connected with matter naturally hard; these fossil shells, therefore, and other productions of the sea found on land, being the spoils of many ages, must necessarily have accumulated into large masses.

We have already remarked the prodigious quantities of shells preserved in marble, limestone, chalk, marl, &c. They appear in masses like hills or mountains; and they often compose more than one half of the bodies in which they are contained. Sometimes they appear entire, and at other times in fragments, but large enough to enable us to distinguish their respective species. Here our knowledge of this subject, derived from observation, stops. But I go farther, and maintain, that shells are the medium employed by nature in the formation of most stones; that chalk, marl, and limestone, consist entirely of the dust or fragments of shells; and, consequently, that the quantity of decomposed shells is infinitely greater than that of those which have been preserved. These positions shall be fully established in the section upon minerals; and I shall only here exhibit the point of view in which the different strata of the earth ought to be considered. The first bed, in which nothing of the original structure appears, is composed of mud deposited by dews, rains, and snow, and of particles of animal and vegetable substances. The inferior beds of chalk, marl, limestone, and marble, are composed of the spoils of shells and other sea-bodies, mixed occasionally with entire shells or fragments of them. But clay and vitrifiable sand are the materials which compose the internal parts of the globe. These substances were

vitified at the time the earth assumed its figure, which necessarily implies, that the whole was then in a melted state. The different species of granite, flint, free-stone in large masses, slate, and coal, derive their origin from sand and clay, and are also disposed in beds. But tufa and pumice, free-stone and flint in small or detached pieces, crystals, metals, pyrites, most minerals, sulphurs, &c. are matters, the formation of which is recent, when compared with that of marble, calcinable stones, chalk, marl, and other substances that are disposed in horizontal beds, and contain shells, or other relics of the ocean.

As the terms I have employed may appear obscure or ambiguous, it is necessary to explain them. By *clays*, I mean not only the white and yellow clays, but likewise the blue, the soft, the hard, the laminated, &c. which I consider to be the scoriæ of glass, or the decompositions of glass. By *sand*, I always understand vitrifiable sand; and I comprehend, under this denomination, not only the fine sand which produces free-stone, and which I maintain to be the powder of glass, or rather of tufa, but also that sand rubbed off free-stone, and the still grosser kind resembling small gravel, proceeding from granite and rock-stone, and which is brittle, angular, and reddish, and generally found in the beds of those rivers which descend precipitantly from hills or mountains composed of granite or

or common rock. The river Armanſon, which runs by Semur in Auxois, where all the ſtones are of common rock, carries down great quantities of this groſs, rough, and brittle ſand. It is of the ſame nature with rock-ſtone, of which it is only ſmall portions, as calcinable gravels are only particles of free-ſtone. Beſides, rock-ſtone and granite are the ſame ſubſtances; but I have uſed both terms, becauſe they are conſidered by ſome as different ſpecies. The ſame may be remarked of flints and of free-ſtone in large maſſes: Theſe alſo are ſpecies of granite; and I call them flints in large maſſes, becauſe, like calcinable ſtones, they are diſpoſed in beds, and alſo to diſtinguiſh them from flints and free-ſtone in ſmall maſſes, as the round flints and ſand-ſtones, which have no continuation, or are not found in beds of any extent. Theſe are recent productions, and have not the ſame origin as flint and free-ſtone in large maſſes, which form regular and extenſive ſtrata. Under *ſlate* I comprehend the blue, the white, the gray, the reddiſh, and all the plated ſtones. Theſe bodies are generally found below laminated clay, and ſeem to be nothing elſe but clay hardened into thin ſtrata by drying; and this is the reaſon of ſo many cracks or fiſſures remarkable in ſuch ſubſtances. Coal and jet are likewiſe referable to clay, and are found under the laminated clays or ſlate. By *tufa* I mean not only the common pumice which is

full of holes, and has an organized appearance, but all beds of stone formed by the sediments of running waters, all the stalactites, incrustations, and every kind of stone that dissolves by fire. It does not admit of a doubt that all these are new substances, and that they are constantly growing. Tufa is only a mass of stony matter, not distinguished by regular strata. This matter is commonly found in small hollow cylinders, is regularly shaped, formed by rills or percolations at the foot or upon the declivities of hills, and consisting of coats of marl or calcareous earth. The cylindric form is the specific character of this kind of tufa, and it is always either oblique or straight, according to the direction of the rills by which it is produced. The extent of these spurious quarries is inconsiderable, and generally proportioned to the height of the mountains which furnish the materials of their growth. The intervals between the cylinders of the tufa, by the daily addition of fresh stony matter, are at last filled up, and the whole assumes a compact and solid form; but it never acquires the hardness of stone, and, for that reason, is denominated by Agricola, *marga tofacea fistulosa*. In the tufa are often found impressions of the leaves of such trees and plants as grow in the neighbourhood; land-shells, well preserved, are likewise frequently found in the tufa, but never sea-shells; it is, therefore, a recent production, and ought to be ranked with
stalactites,

stalactites, incrustations, &c. All these new substances are a kind of spurious stones, formed by the wasting of others, but never arrive at the consistence of real petrification.

Cryſtal, precious stones, every stone that has a regular figure, and even flints in small masses, and consisting of concentric coats, whether found in the perpendicular fissures of rocks, or elsewhere, are only exudations, or the concreting juices of flint in large masses; they are, therefore, new and spurious productions, the genuine stalactites of flint or of granite.

Shells are never found in common rock or granite, nor in free-stone, although they often appear in vitrifiable sand, from which free-stone derives its origin. This circumstance seems to indicate, that sand, unless when perfectly pure, cannot unite into free-stone or granite; and that a mixture of shells, or of other heterogeneous bodies, totally prevents it from cementing. I have often examined those small round stones, found in beds of sand which are mixed with shells; and never could discover in them a single shell. These round stones are true concretions of free-stone, formed in those places where the sand is pure, and not mixed with heterogeneous matter; which is the reason why no larger masses are produced.

We formerly remarked, that, at Amsterdam, which is a very low country, sea-shells were found 100 feet below the surface, and at Marly-la-Ville,

la-Ville, 6 leagues from Paris, at the depth of 75 feet. They have also been found in mines below beds of rock of 50, 100, 200, and even of 1000 feet thick, as is apparent in the Alps and Pyrennees, where shells and other sea-bodies are found in the inferior strata of immense rocks, which have been cut through in a perpendicular direction. But to proceed in order: Shells are found in the mountains of Spain, France, and England, in all the marble quarries of Flanders, in the mountains of Gueldres, in all the hills round Paris, in those of Burgundy and Champagne; in a word, in all places where the basis is not composed of free-stone or tufa; and, in all these places, the substance of the stones consists more of shells than of any other matter. By shells, I mean not only the remains of shell-fish, but likewise those of crustaceous animals, the bristles of sea-hedge-hogs, and all the productions of sea-insects, as corals, madrepores, astroites, &c. Any man may be convinced, by the evidence of his own eyes, that, in most marbles and calcinable stones, the proportion of sea-bodies is so great, as to exceed the matter by which they are united.

But, farther, sea-bodies are found even on the tops of the highest mountains of the Alps; for example, on the top of Mount Cenis, in the mountains of Genes, in the Apennines, and in most of the stone and marble quarries of Italy. They appear in the stones of which the most ancient

ancient buildings in Rome are constructed, in the mountains of Tirol, in the centre of Italy, on the top of Mount Paternè near Boulogne, in the hills of Pouille, in those of Calabria, in many parts of Germany and of Hungary, and, lastly, in all the high grounds of Europe*.

In Asia and Africa, travellers have observed sea-shells in several places; for example, 'upon the Castravan mountains, above Baruth,' says Shaw†, 'where there is a curious bed of whitish stone, but of the slate-kind, which contains, in every fleck of it, a great number and variety of fishes. These, for the most part, lie exceedingly flat and compressed, like the fossil fern plants; yet, at the same time, they are so well preserved, that the smallest strokes and lineaments of their fins, scales, and other superficial diversities, are easily distinguished.' Between Cairo and Suez, and particularly upon all the hills of Barbary, says the same author, are many petrified shells and echini; most of them exactly correspond with the different species still existing in the Red Sea. As to Europe, petrified fishes are to be met with in Switzerland, Germany, the quarry of Oningen, &c.

Fossil shells, says M. Bourguet, are to be found in the long chain of mountains stretching from Portugal to the most easterly parts of China, in the valleys of Europe, and in all the

* See Steno, Ray, Woodward, &c.

† See Shaw's Travels, p. 344.

mountains of Africa and America; and hence, he remarks, we may conclude, that they also exist in those parts of the globe with which we are still unacquainted.

The islands of Europe, of Asia, and of America, wherever men have had occasion to dig, whether in the mountains or in the valleys, furnish many specimens of fossil shells; and this circumstance demonstrates, that islands are analogous in structure and formation to their neighbouring continents*.

These facts are sufficient to prove, that fossil shells, petrified fishes, and other productions of the ocean, exist in great quantities in almost every place where proper investigations have been made. 'It is true,' says Tancrid Robinson, 'that sea-shells are dispersed occasionally on the earth by armies, and by the inhabitants of towns and villages. La Loubere relates, in his voyage to Siam, that the monkeys of the Cape of Good Hope perpetually amuse themselves by transporting shells from the shores of the sea to the tops of the mountains. But this is no solution to the question, why these shells are dispersed through every climate of the earth, or why they are found in the bowels of the highest mountains, and disposed in beds, like those in the bottom of the ocean.'

Upon perusing an Italian letter, printed at Paris in the year 1746, concerning the changes

* See *Lettres philosoph. sur la formation des fels*, p. 205.

this globe has undergone, I was astonished to find a repetition of Loubere's sentiments. Petrified fishes, in the opinion of this writer, are always of rare species, which were rejected from the Roman tables, because they were not esteemed to be wholesome: And as to fossil shells, he says, that the pilgrims brought from Syria, in the time of the crusades, those shells peculiar to the Levant, which are now found petrified in France, in Italy, and in other parts of Christendom. Why did he not add, that the monkeys transported shells to the tops of the highest mountains, which never were inhabited by men? This he might have done with great facility, and it would have given an air of credibility to his hypothesis! How should men, who pretend to philosophy, differ so widely in their opinions? It is not sufficient, it would appear, to find fossil shells in almost every part of the earth where pits have been dug, nor to have quoted the testimonies of natural historians, as these authors may, according to certain systems, have imagined that shells existed where none were to be found: We shall, therefore, to prevent all prejudices of this kind, quote the authority of some authors who had no theory to support, and whose habits of observation could only enable them to recognise shells that were entire, and in the best preservation. This testimony will, perhaps, have greater authority with men who cannot judge of the facts,

facts, nor know the distinction between real shells and their petrifications.

Every man may examine with his eyes the banks of shells in the hills round Paris, and especially in the stone-quarries, as at Chauffée near Seve, at Iffy, Passy, and other places. A great quantity of lenticular stones are to be found at Villers-Cotterets; the rocks are almost entirely composed of these stones; and they are irregularly interspersed with a kind of cement, by which they are united. At Chaumont, the quantity of shells is so great, that the whole hills, which are pretty high, appear to consist of nothing else. The same phænomenon is exhibited at Courtagnon near Rheims, where there is a bank of shells of about four leagues broad, and the length is still more considerable. I mention these places, because they are famous, and the shells strike the eye of every beholder.

With regard to foreign countries, let us attend to the remarks of travellers.

‘ In Syria and Phœnicia, in the neighbourhood particularly of Latikea, the rocks are of a hard chalky substance, from whence the adjacent city might borrow the name of the *White Promontory*. The Nakoura, formerly called the *Scala Tyrriorum*, is of the same nature and complexion; both of them including a great variety of corals, shells, and other remains of the deluge*.’

* See Shaw's Travels, p. 344.

‘ But fossil shells, and other the like testimonies of the deluge, are very rare in the mountains near Sinai, the original menstruum, perhaps, of these marbles, being too corrosive to preserve them. Yet, at Corondel, where the rocks approach nearer to our free-stone, I found a few *chamæ* and *pectunculi*, and a curious *echinus* of the discoid kind. The ruins of the small village at Ain-el-Moussa, and the several conveyances we have there for water, are all of them full of fossil shells. The old walls of Suez, and the remains that are left us of its harbour, are likewise of the same materials, all of them probably from the same quarry. Between Suez and Cairo, likewise, and all over the mountains of Lybia, near Egypt, every little rising ground and hillock discovers great quantities of the *echini*, as well as of the bivalve and turbinated shells, most of which exactly correspond with their respective families still preserved in the Red Sea *.’

The moving sand in the neighbourhood of Raz Sem, in the kingdom of Barca, covers many palm-trees, *echini*, and other petrifications. *Raz Seme* signifies *the head of a fish*, and is the name of what is called the petrified village, where it has been alledged, that men and women, with their children, cattle, furniture, &c. may be seen converted into stone. ‘ But,’ says Mr. Shaw, ‘ all this is mere fiction, as I learned not only

• Shaw’s Travels, p. 444.

‘ from

‘ from Mr. Mair, Consul at Tripoli, who sent several people to examine into the fact, but also from men of credit and learning who had been on the spot.’

Near the Pyramids Mr. Shaw discovered some stones which had been hewn by workmen, and were mixed with little round bodies like lentils, and some of them resembled barley half peeled. ‘ These,’ he says, ‘ were supposed to have been fragments of victuals left by the workmen, and are now petrified. But this account appears to be very improbable,’ &c. These lentils and grains of barley are nothing but petrified shells, known to every naturalist by the name of lentil-stones.

‘ Many fossil stones,’ says Miffon *, ‘ are found in the neighbourhood of Maestricht, especially near the village of Zichen or Tichen, and in the mountain called the *Huns*.

‘ In the environs of Sienne, near Certaldo, are many mountains of sand filled with different kinds of shells. Monte-mario, about a mile from Rome, is also full of them. I have remarked them in the Alps, in France, and in other places. Orlearius, Steno, Cambden, Speed, and many other writers, have related the same phænomena †.

‘ The island of Cerigo,’ says Thevenot ‡, ‘ was called *Porphyris* by the ancients, on ac-

* See Voyage de Miffon, tom. 3. p. 109.

† Ibid. tom. 2. p. 312.

‡ Voyage de Thevenot, tom. 1. p. 25.

‘ count of the quantities of porphyry found in
 ‘ it.’ Now, porphyry, as observed above, is
 composed of the prickles of the echinus, or sea-
 hedge-hog, united by a very hard stony cement.

‘ Opposite to Inchené, a village on the east
 ‘ bank of the Nile, I found petrified plants
 ‘ growing naturally on a piece of ground about
 ‘ two leagues in length, and of an inconsiderable
 ‘ breadth. This is one of the most singular
 ‘ productions in nature. The plants resembled
 ‘ the white corals which grow in the Red Sea*.’

‘ There are several species of petrification on
 ‘ Mount Libanus, and, among others, flat stones
 ‘ which contain the skeletons of fishes entire,
 ‘ and well preserved; chesnuts, and small
 ‘ branches of coral, of the same species with
 ‘ what grows in the Red Sea, are likewise found
 ‘ on this mountain †.’

‘ In mount Carmel,’ says Shaw, ‘ we gather a
 ‘ great many hollow stones, lined in their insides
 ‘ with a variety of sparry matter, which, from
 ‘ some distant resemblance, are said to be petri-
 ‘ fied olives, melons, peaches, and other fruit.
 ‘ These are commonly bestowed upon pilgrims,
 ‘ not only as curiosities, but as antidotes against
 ‘ several distempers. The olives, which are
 ‘ *lapides Judaici*, as they are commonly called,
 ‘ have been always looked upon, when dissolved
 ‘ in the juice of lemons, as an approved medi-

* See Voyage de Paul Lucas, tom. 2. p. 380.

† Ibid. tom. 3. p. 326.

‘ cine against the stone and gravel *.’ These *lapides Judaici* are the points of the echinus.

‘ M. la Roche, a physician, gave me some petrified olives, called *lapides Judaici*, which grow in great quantities upon the mountains, where are to be found, according to my information, other stones, which in their inside contain perfect representations of the natural parts of men and women †. These are the hyfterolithes.’

‘ In going from Smyrna to Tauris,’ says Tavernier, ‘ when we came to Tocat, the heat was excessive ; we therefore left the common road to the north of us, and went by the mountains, where there are always shade and cool breezes. In many places we found snow ; and, upon the tops of some of these mountains, we saw shells resembling those upon the sea-shore, which is an extraordinary phænomenon.’

Let us attend to what Olearius says concerning the petrified shells he observed in Persia, and in the rocks where the sepulchres have been cut near the village Pyrmarus.

‘ Three of us ascended, by mutually assisting each other, the most frightful precipices, and at last gained the summit, where we found four large chambers, with several niches cut out of the solid rock : But what struck us most was, to find in this vault, on the top of the

* See Shaw's Travels, p. 444.

† Voyag. de Monconys, p. 334.

‘ mountain,

‘ mountain, muscle-shells ; and in some parts
 ‘ they appeared in such quantities, that this
 ‘ whole rock seemed to consist of nothing but
 ‘ sand and shells. In returning from Persia,
 ‘ we perceived several of these shelly mountains
 ‘ upon the coasts of the Caspian Sea.’

To these authorities many others might be added, were I not apprehensive of tiring those who need no additional proofs on this subject, and who have perceived with their eyes, as I have done, the existence of shells in all places where they have been searched for.

In France, we find not only the shells belonging to our own coasts, but those which never appeared in our seas. Some philosophers even alledge, that the number of foreign petrified shells greatly exceed those of our own climate. But this opinion seems not to be well founded ; for, independent of such shells as lie in the bottom of deep water, and are seldom brought up by fishers, and, of course, are regarded by us as foreigners, though they may exist in our seas, I find, upon comparison, that more of the petrified shells belong to our own shores than to any other. For example, all the peclines, most cockles, muscles, oysters, trumpet-shells, ear-shells, limpets, nautili, stars, tubulites, corals madrepores, &c. which are found so universally, are really produced in our seas : And, though many sea-bodies appear, which are either foreign or unknown, as the cornu ammonis, the lapides

pides Judaici, the large screw, the buccinum, called *abajour*, &c. yet I am convinced, by repeated observation, that the number of these species is inconsiderable, when compared with the shells which belong to our own coasts. Besides, the madrepores, astroites, and all those sea-bodies formed by insects, constitute the basis of our marbles and lime-stone; for the shells, however abundant, make but a small part of these stones, and many of them are produced in our own seas, and particularly in the Mediterranean.

The Red Sea produces corals, madrepores, and sea-plants, more abundantly than any other. The port of Tor furnishes an amazing quantity. In calm weather, the quantity exhibited is so great, that the bottom of the sea resembles a forest. Some of the branched madrepores rise from eight to ten feet high. They are also very common in different parts of the Mediterranean; and are to be found in all gulfs, islands, &c. of every temperate climate, where the sea is not very deep.

Mr. Peyssonel was the first who discovered that coral, madrepores, &c. were not plants, but that they derived their origin from animals. The truth of this discovery was long doubted. Some naturalists at first rejected it with disdain. But it soon gained universal assent; and every man is now satisfied, that what was formerly called sea-plants, are nothing but hives, or rather lodges, formed by insects for their own habitation.

habitation. These bodies were originally classed with minerals, then with plants, and now they must for ever be recognised as the genuine operation of animals.

Many shell-fish inhabit the deepest parts of the ocean, and are never thrown upon the coasts; authors have, therefore, termed them *Pelagiæ*, to distinguish them from the other kinds, which they call *Littorales*. It is probable that the cornu ammonis, and some other species, found only in a petrified state, belong to the former, and that they have been impregnated with stony matter in the very places where they are discovered. It is also probable, that the species of some animals have been extinguished, and that these shells may be ranked among their number. The extraordinary fossil bones found in Siberia, in Canada, in Ireland, and several other places, seem to confirm this conjecture; for no animal has hitherto been discovered to whom bones of such enormous size could possibly belong.

Fossil shells, says Woodward, are found from the top to the bottom of quarries, in pits, and in the deepest mines of Hungary: And we are informed by Mr. Ray, that they are found in the rocks on the shores of Calda, and in Pembroke-shire, at the depth of 200 fathoms*.

Shells not only appear in a petrified state at great depths, and on the tops of the highest mountains, but they are also found in their na-

* See Ray's discourses, p. 178.

tural condition, having the colour, lustre, and lightness of sea-shells; so that, to be fully satisfied on this subject, nothing farther is requisite than to compare them with the shells found on the shores of the sea. The slightest examination will convince us, that petrified and fossil shells are precisely the same with those of the ocean; for they are marked with the same furrows and articulations, however minute; and, in the glossopetri and other teeth of fishes, which are sometimes found adhering to the jaw-bone, it is obvious, that the teeth are worn and polished at the extremities, and that they have been used by the living animals.

Fossil shells are almost every where to be met with; and, of those of the same species, some are small, others large, some young, others old, some entire, others imperfect; and sometimes young ones appear adhering to the old.

The shell-fish called *Purpura* has a long tongue the extremity of which is so sharp and osseous, that it pierces the shells of other fishes, in order to extract nourishment from them. Shells pierced in this manner are often found in the bowels of the earth; which is an incontestible proof that they were formerly inhabited by living fishes, and that they existed in the same places with the *purpura**.

The obelisks of St. Peter's at Rome, according to John of Latran, were said to have been

* See Woodward, p. 296. 300.

brought

brought from the Egyptian pyramids: They consist of a red granite, which, as formerly remarked, contains no shells. But the ancient marbles of Africa and Egypt, and the porphyry said to have been brought from Solomon's temple, and the palaces of the Egyptian kings, and employed in several of the Roman buildings, are full of shells. Red porphyry is composed of an infinite number of the prickles of that species of echinus called a sea-chestnut; they are placed very near each other, and form the white points of the porphyry. Each of these points have a black speck in the middle, which is the section of the longitudinal tube of the prickle of the echinus. At Ficin in Burgundy, three leagues from Dijon, there is a red stone so similar to porphyry, that it differs only in density, not being harder than marble: It is entirely composed of the points or prickles of the echini, and the stratum of it is considerable both in thickness and extent. Many excellent pieces of workmanship are made of it in this province, and particularly the steps which lead to the pedestal of the equestrian statue of Louis le Grand, at Dijon. This species of stone is also found in Montbard in Burgundy; it is softer than marble; but it contains still more prickles of the echini, and a smaller proportion of red matter. Thus the ancient porphyry of Egypt, and the porphyry of Burgundy, differ only in the degree of hardness, and in the quantity of prickles

prickles or points of the echinus contained in them.

With regard to what is called green porphyry, I imagine it to be rather a granite than a porphyry. It is not, like the red porphyry, composed of the prickles of the echinus; and its substance has a greater resemblance to that of common granite. The ancient walls of Volaterra in Tuscany have been built of stones in which are many shells, and these walls were erected 2500 years ago*. Most marbles, porphyries, and other stones employed in the buildings of the ancients, contain shells and other productions of the ocean, in the same manner as some of our modern marbles. Hence we may conclude, that, independent of the testimony of holy writ, the earth, before the deluge, was composed of the same materials as at present.

Upon the whole, it is apparent, that petrified shells are found in Europe, in Asia, in Africa, and in every place where proper researches have been made. They are also found in America, in the Brasils, for example, in Tucumana, in Terra Magellanica, and in such vast quantities in the Antilles, that what the inhabitants call lime, which lies immediately below the soil, is nothing but a congeries of shells, corals, madrepores, astroites, and other sea-bodies. These incontestible facts would have led me to conclude, that petrified shells, and other productions of the

* See Steno de solido intra solidum, p. 63.

ocean, were to be found through the whole continent of America, and especially in the mountains, as Woodward affirms. But M. de la Condamine, who lived several years in Peru, assures me, that he was never able to discover any of them in the Cordeliers, although he had diligently searched for them. This phenomenon would indeed be singular, and would lead to conclusions still more uncommon. But, I confess, the testimony of this celebrated observer notwithstanding, I am strongly inclined to believe that there is, in the mountains of Peru, as well as every where else, petrified shells and other sea-bodies, although they have not yet been discovered. In matters which depend on testimony, the positive evidence of two witnesses is a complete proof; but the evidence of ten thousand witnesses, who only declare in the negative, that they never observed a particular appearance, gives rise to nothing more than a slight doubt. Thus reason, joined to the force of a general analogy, obliges me to persist in believing that fossil shells will still be found in the mountains of Peru, especially if they are searched for in the sides, and not on the very summits.

The tops of high mountains are generally composed of granite, ~~free~~ ^{free}-stone, and other vitrifiable materials, which never contain shells. These matters were all formed out of beds of sand, when they were covered by the sea. But, when the waters left the mountains, they would

carry off the sand, and other light bodies, into the plains, and leave nothing on their tops but those beds of rock which had been formed below the stratum of sand. At two, three, or four hundred fathoms below the summit of these mountains, we often find marbles and other calcinable matters, disposed in parallel beds, and containing shells and other sea-bodies. Hence, if M. de la Condamine examined only the most elevated places, which consist of granite, of freestone, or of vitrifiable sand, it is not surprising that he did not find fossil shells. But he ought to have explored the lower parts of the Cordeliers, and he would unquestionably have discovered beds of marble, earth, &c. mixed with shells; for such beds have been found in every part of the world that has undergone a proper examination.

But, supposing it to be a fact, that there are no productions of the ocean in the mountains of Peru, nothing could be concluded from which could affect our theory. Some parts of the globe, and particularly places of such elevation as the Cordeliers, might never have been covered with the sea. These mountains, however, would be an ample field for curious observation. They would not, in that case, consist of parallel beds. Their materials would be very different from all others: They would have no perpendicular fissures: The structure of the stones and rocks would have no resemblance to those of
other

other countries: *Lastly*, These mountains would exhibit the ancient structure of the earth before it was changed by the motion of the waters; they would discover the primitive state of the globe, its original form, the natural arrangement and connection of its parts. But this notion is supported by too slender a foundation; and it is more consonant to the rules of philosophy to believe that fossil shells exist in the mountains of Peru, in the same manner as they exist every where else.

With regard to the position of shells in beds of earth or of stone, let us attend to the following passage of Woodward: ‘ All the shells that
 ‘ are found in numberless strata of earth, and
 ‘ rocks, in the highest mountains, and in the
 ‘ most profound quarries and mines, in flint,
 ‘ cornelian, agate, &c. and in masses of sulphur,
 ‘ marcasites, and other mineral and metallic bo-
 ‘ dies, are filled with the same substances that
 ‘ compose the strata in which they are included,
 ‘ and never with any heterogeneous matter;’
 p. 206. &c.—‘ We now find in the sand-
 ‘ stone of all countries, (the specific gravity of
 ‘ the several sorts whereof is very little different,
 ‘ being generally to water as $2\frac{1}{2}$ or $\frac{9}{8}$ to 1)
 ‘ only those conchæ, pectines, cochleæ, and
 ‘ other shells that are nearly of the same gra-
 ‘ vity, viz. $2\frac{1}{2}$ or $2\frac{5}{8}$ to 1. But there are ordi-
 ‘ narily found enclosed in it prodigious num-
 ‘ bers; whereas, of oyster-shells, (which are in
 ‘ gravity

' gravity but as about $2\frac{1}{3}$ to 1) of echini, (which
 ' are but as 2 or $2\frac{1}{8}$ to 1) or the other lighter
 ' kinds of shells, scarce one ever appears therein.
 ' On the contrary, in chalk (which is lighter
 ' than stone, being but as about $2\frac{1}{10}$ to 1) there
 ' are only found echini, and the other lighter
 ' sorts of shells;' p. 32, 33.

It must here be remarked, that what Woodward says with respect to specific gravity, is not universally true; for shells of different specific gravities are often found in the same matters; shells of cockles, of oysters, and of echini, for example, are found in the same bed of stones or of earth. In the cabinet of the French King, there is a cockle petrified in a cornelian, and echini petrified in an agate. Hence the difference in the specific gravity of shells has had less influence upon their position in the strata of the earth than Woodward would have us to believe. The reason why the shells of the echini, and others of a light texture, abound so much in chalk, is owing to this circumstance, that chalk itself is only decomposed shells; those of the echini being lighter and thinner than others, would be most easily reduced to powder or chalk; and hence beds of chalk could exist only in those places where were formerly collected by the sea great quantities of light shells, the destruction of which would form that chalk in which we still find shells that have resisted the operation

operation of time, either in an entire state, or in fragments sufficient to discover their species.

This subject shall be more fully treated of in the article concerning Minerals. I shall here only observe, that Woodward's expressions are often too general. He appears to assert, that shells are found as frequently, and in as great abundance, in flints, cornelians, chalcedonii, ores, and sulphur, as in other matters. But the fact is, that shells are a very rare phenomenon in vitrifiable or purely inflammable substances; and, in chalk, marl, and marbles, the quantity of them is so prodigious, that it is impossible to affirm that the lighter and heavier shells are uniformly found in strata corresponding to their specific gravities, though, in general, this may be the case, oftener than otherwise. They are all impregnated with the bodies in which they are immersed, whether in the horizontal beds, or in the perpendicular fissures; because the whole has been affected by the operation of water, though at different times and in different manners. Those found in the horizontal beds of stone, marble, &c. have been transported and deposited by the waves of the sea; and those found in flints, cornelians, and other matters, peculiar to the perpendicular fissures, were formed by rills of water impregnated with lapidific or metallic substances. In both cases, the matter that fills the shells has been in the state of a fine impalpable

pable powder ; because every pore of them is completely filled, and the moulds of them are as exact as the impressions of a seal upon wax.

It is, therefore, apparent, that, in stone, marble, &c. there are multitudes of shells so entire, and so well preserved, that they may be compared with those in our cabinets, or upon the shores of the sea.

‘ There being, I say, besides these, such vast
 ‘ multitudes of shells contained in stone, &c.
 ‘ which are entire, fair, and absolutely free from
 ‘ any such mineral contagion ; which are to be
 ‘ matched by others at this day found upon our
 ‘ shores, and which do not differ in any respect
 ‘ from them ; being of the same size that those
 ‘ are of, and the same shape precisely ; of the
 ‘ same substance and texture, as consisting of the
 ‘ same peculiar matter, and this constituted and
 ‘ disposed in the same manner as is that of their
 ‘ respective fellow-kinds at sea ; the tendency
 ‘ of the fibres and striæ the same ; the compo-
 ‘ sition of the lamellæ, constituted by these
 ‘ fibres, alike in both ; the same vestigia of ten-
 ‘ dons (by means whereof the animal is fasten-
 ‘ ed and joined to the shell) ; in each the same
 ‘ papillæ ; the same sutures, and every thing
 ‘ else, whether within or without the shell, in
 ‘ its cavity, or upon its convexity, in the sub-
 ‘ stance, or upon the surface of it. Besides,
 ‘ these fossil shells are attended with the ordi-
 ‘ nary

' nary accidents of the marine ones, *ex. gr.* they
 ' sometimes grow to one another, the lesser shells
 ' being fixed to the larger: They have the bala-
 ' ni, tubuli vermiculares, pearls, and the like,
 ' still actually growing upon them. And, which
 ' is very considerable, they are most exactly of
 ' the same specific gravity with their fellow-kinds
 ' now upon the shores. Nay farther, they an-
 ' swer all chymical trials in like manner as the
 ' sea-shells do; their parts, when dissolved, have
 ' the same appearance to view, the same smell
 ' and taste*.'

I have often observed, with astonishment,
 whole mountains, chains of rocks, and extensive
 quarries, so full of shells, and other sea-bodies,
 that there was hardly space left for the matters
 in which they are deposited.

I have seen some arable fields so full of pe-
 trified cockles, ~~that~~ they might be picked up by
 a blind man, others entirely covered with cornu
 ammonis, and others with cardites; and the more
 this subject is inquired into, we shall be the
 more thoroughly convinced, that the number of
 petrifications is infinite, and that it was absolute-
 ly impossible that all the animals which inhabited
 these shells could exist at the same time.

I have farther remarked, that the stones of
 those arable lands which abound with petrified
 shells in an entire form, well preserved, and de-
 tached from all other matter, are frittered down

* Woodward, p. 23, 24.

by frost, which destroys stones, but has little effect upon petrified shells.

These immense quantities of petrified sea-bodies, found in so many different places and situations, prove, that they could not be transported and deposited by the waters of the deluge; for the greatest part of them, instead of being found in the bowels of the earth, and in solid marble at the depth of seven or eight hundred feet, must have remained on the surface.

In all quarries, petrified shells form part of the internal structure of the stone, the surface of which is often covered with stalactites, a matter much less ancient than the stone that contains the shells. Another proof that these shells could not be derived from the deluge is, that the bones, horns, claws, &c. of land-animals, are seldom found in a petrified state, and are never incorporated in marble, or other hard stones; whereas, if these effects had been produced by the deluge, the remains of land-animals would have been found in marbles, as well as those of fishes.

To alledge, that the earth was entirely dissolved at the time of the deluge, is a mere gratuitous supposition, which required a second miracle in order to give water the power of an universal dissolvent. Besides, it infers an evident contradiction; for, if water was then an universal menstruum, how could shells have been preserved in the entire state in which we find them?

This

This is an evident demonstration, that no such dissolution took place, and that the parallel strata were not formed in an instant, but were gradually produced by successive sediments; for, it is apparent to every observer, that the disposition of all the materials composing the earth has been occasioned by the operation of water. The only question, therefore, that remains, is, Whether this arrangement of parts was produced all at once, or in a succession of time? Now, it has already been shown, that it could not possibly happen at one time; because the materials are not disposed according to their specific gravities, and because they never suffered a general dissolution. This arrangement, therefore, must have originated from successive sediments. Any other cause, or particular revolution, would have given rise to an arrangement totally different. Besides, particular revolutions, or accidental causes, could never have produced a uniform disposition of horizontal and parallel strata throughout the whole globe.

Let us attend to what the historian of the Academy * has said upon this subject.

‘ The many marks of extensive inundations,
 ‘ and the manner in which mountains must be
 ‘ conceived to have been produced, demonstrate,
 ‘ that the surface of this earth has suffered great
 ‘ revolutions. However deep we penetrate in-

* Année 1718, p. 3.

' to the globe, we discover nothing but ruins,
 ' bodies of different kinds amassed and incor-
 ' porated without any order or apparent design.
 ' If there be any regularity in the structure of
 ' the earth, it lies too deep for our researches ;
 ' we must, therefore, confine ourselves to the
 ' ruins of the external crust, which will be suf-
 ' ficient to occupy the attention of philosophers.

' M. de Jussieu discovered, in the neighbour-
 ' hood of St. Chaumont, a great quantity of
 ' slaty or laminated stones, every lamina of
 ' which was marked with the impressiion of a
 ' stem, leaf, or other portion of some plant.
 ' The impressiions of leaves were uniformly
 ' extended, as if they had been stretched in
 ' the stones by the hand ; a clear demonstration,
 ' that they had been transported by water,
 ' which always keeps leaves in that position :
 ' their situations were various, and sometimes
 ' they lay across each other.

' It is natural to imagine, that a leaf deposited
 ' by water upon soft mud, and then covered
 ' by a similar layer of mud, would impress
 ' upon the undermost layer the figure of its one
 ' side, and upon the uppermost the figure of its
 ' opposite side ; and, after these layers hardened
 ' and petrified, that they would each bear an
 ' impressiion of a different side of the leaf. But
 ' this supposition, however natural, does not
 ' take place : the two laminæ of stone uni-
 ' formly

‘ formerly bear the impressi^on of the same side
 ‘ of the leaf, the one in alto, the other in bas-
 ‘ relief. For this observation, with regard to
 ‘ the figured stones of St. Chaumont, we are in-
 ‘ debted to M. de Jussieu ; but we leave the ex-
 ‘ plication of it to himself, and shall proceed to
 ‘ remarks of a more general and interesting na-
 ‘ ture.

‘ All the impressi^ons on the stones of Saint
 ‘ Chaumont are of foreign plants, which are
 ‘ not to be found in any part of France ; they
 ‘ are natives either of the East Indies, or of the
 ‘ warmer climates of America. Most of them
 ‘ belong to the capillary tribes, and they are ge-
 ‘ nerally particular species of ferns, the close
 ‘ texture of which enables them both to make
 ‘ deep impressi^ons, and to remain long in a state
 ‘ of preservation. M. Leibnitz was astonished
 ‘ to find the impressi^ons of the leaves of a few
 ‘ East India plants upon some stones in Ger-
 ‘ many : In the example under consideration,
 ‘ the wonder is greatly augmented ; for, by
 ‘ some unaccountable destination of nature, it
 ‘ would appear, that, in all the stones of Saint
 ‘ Chaumont, not a single impressi^on of a native
 ‘ plant is to be found.

‘ From the number of fossil shells in the
 ‘ mountains and quarries exhibited in this coun-
 ‘ try, as well as in many others, it is apparent,
 ‘ that it must have formerly been covered with

‘ the sea. But how could the American or Indian oceans come hither ?’

‘ To solve this and other surprising phenomena, we may suppose, with much probability, that the sea originally covered the whole globe. But this supposition will not answer ; because no terrestrial plants could then exist : The plants of one country, therefore, could only be transported to another by great inundations.

‘ M. de Jussieu imagines, that, as the bed of the sea is always rising higher by means of the mud and sand incessantly carried into it by the rivers, the sea, at first confined by natural dikes, might at last surmount them, and spread over the land to great distances ; or, which would produce the same effect, the dikes might in time be rendered so thin, by the constant operation of the water, that ~~they~~ would at last give way. Soon after the formation of the earth, when nothing had assumed a regular or settled form, sudden and prodigious revolutions might then be produced, of which we have now no examples, because every thing is in such a fixed and permanent state, that only slow and inconsiderable changes can take place : It is for this reason that we find a difficulty in crediting revolutions more sudden and tremendous.

‘ By

‘ By some of these great revolutions the West
‘ or East Indian Oceans might have been poured
‘ in upon Europe : In their journey, they would
‘ tear up foreign plants, carry them off floating
‘ on the waves, and gently deposit them in
‘ shallow places, from which the waters would
soon evaporate.’

P R O O F S

O F T H E

T H E O R Y O F T H E E A R T H .

A R T I C L E I X .

Of the Inequalities upon the Earth's Surface.

THOUGH the inequalities upon the surface of the earth may be considered as a deformity in its figure, they are absolutely necessary to vegetation and animal life. To be convinced of this fact, we need only consider what would be the condition of the earth, were its surface perfectly smooth and regular. Instead of those beautiful hills which furnish abundance of water for supporting the verdure of the earth, instead of those richly garnished fields, where plants and animals find an easy and comfortable subsistence, a dreary ocean would cover the whole globe, and the earth, deprived of all its valuable

valuable and alluring qualities, would be an obscure abandoned planet, suited only for the habitation of fishes.

But, independent of moral considerations, which seldom ought to be employed in natural philosophy, the surface must, from a physical necessity, have been irregular; for, supposing it to have been originally smooth and level, the motion of the waters, subterraneous fires, the winds, and other external causes, would necessarily produce, in time, irregularities similar to those which we now behold.

Next to the elevation of mountains, the depths of the ocean form the greatest inequalities. This depth is exceedingly diversified, even at great distances from land. In some places the sea is said to be a league in depth; but that is a rare phenomenon; and the most common depths are from 60 to 150 fathoms. Gulfs and branches of the ocean which run in upon the land, are still less deep; and straits are generally the most shallow places.

Depths are commonly sounded by a piece of lead, of 30 or 40 pounds weight, fixed to a small rope. This method answers well enough for ordinary depths, but it is liable to error when the depth is very great; for the cord being specifically lighter than water, after much of it has been wound down, the weight of the lead and that of the cord become nearly equal to their bulks of water; then the lead descends no more,

but runs off in an oblique line, and floats at the same depth. Hence, in sounding great depths, an iron chain, or some body heavier than water, should be employed. It is for want of attention to this circumstance, that some navigators have been led to maintain, that the sea, in many places, has no bottom.

In general, the depths in open seas augment or diminish in a pretty regular manner, being commonly deeper the farther from land. But to this remark there are many exceptions; for there are places in the middle of the sea, as at the *Abrolhos* in the Atlantic, where large shelves appear; and there are, in other places, vast sand-banks, well known to the mariners who sail to the East Indies.

Along coasts, the depths are likewise very irregular. However, it may be laid down as a certain rule, that the depth is always proportioned to the height of the coast: The same observation applies to rivers.

It is easy to measure the height of mountains, either geometrically, or by the barometer. This instrument determines the height of a mountain pretty exactly, especially in countries where its variation is not considerable, as at Peru and other equatorial climates. By one or other of these methods, the height of most mountains has already been ascertained; for example, it has been found, that the highest mountains of Switzerland exceed Canigau, the most elevated of the

the Pyrennees, 1600 fathoms*. These mountains appear to be the highest in Europe, since they give rise to a great number of rivers which run into different and very distant seas, as the Po, which empties itself in the Adriatic, the Rhine, which loses itself in the sands of Holland, the Rhone, which falls into the Mediterranean, and the Danube, which runs into the Black Sea. These four rivers, the mouths of which are so distant, derive part of their waters from St. Godard and the neighbouring mountains; a clear proof that this place is the most elevated part of Europe.

Mount Taurus, Imaus, Caucasus, and the mountains of Japan, are higher than any in Europe. The mountains of Africa, as the great Atlas, and the mountains of the Moon, are at least equally high with those of Asia; and the highest of all are those of South America, and especially of Peru, which are 3000 fathoms above the level of the sea. In general, the tropical mountains are more elevated than those of the temperate zones, and those of the latter are higher than those nearer the poles. Thus, the nearer the equator, the greater are the superficial inequalities, which, though considerable with regard to us, are nothing when estimated in relation to the whole globe. A difference of 3000 fathoms in 3000 leagues diameter, is but a fathom to a league, or a foot to 2200 feet, and, upon a globe

* See Hist. de l'Acad. 1708, p. 24.

of $2\frac{1}{2}$ feet, would not make the 16th part of a French line. Hence this earth, which to us appears to be traversed and intersected by mountains of an enormous height, and by seas of a dreadful depth, is, in relation to its size, but slightly furrowed with inequalities so inconsiderable, that they cannot make any variation upon its general figure.

In continents, the mountains form continued chains; but, in islands, they are more interrupted, generally rise in the form of a cone, or pyramid, and are distinguished by the name of peaks. The Peak of Teneriffe, in the Island of Fer, is one of the highest mountains in the earth; it is nearly a league and a half perpendicular above the level of the sea. The Peak of St. George in one of the Azores, and the Peak of Adam, in the Island of Ceylon, are likewise exceedingly high. These peaks are composed of rocks, piled above each other; and all of them throw out, from their summits, fire, ashes, bitumens, minerals, and stones. Some islands, as St. Helena, Ascension Isle, and most of the Canaries and Azores, are only the tops or points of mountains. It is also worthy of remark, that the middle of most islands, promontories, and capes, is the most elevated, and that they are generally divided into two parts, by chains of mountains which run in the direction of their greatest length: In Scotland, for example, the Grampian mountains (Grans-bain) extend from east to west, and divide the island of Great Britain into
two

two parts: The same thing takes place in Sumatra, the Lucca Islands, Borneo, Celebes, Cuba, St. Domingo, the peninsulas of Corea and Malaya, &c. Italy is also longitudinally traversed by the Apennines.

Mountains, as mentioned above, are of different heights; the hills are lowest; then follow the mountains of an ordinary height, which are succeeded by a third range still higher. All these are commonly covered with trees and plants; but neither of them furnish springs except at their bottoms. In the last and highest range, we find nothing but sand, loose stones, flints, and rocks, the tops of which often reach above the clouds. Precisely at the foot of these rocks, are little plains, or hollows, which collect rains and snow, and form those ponds, morasses, or fountains, from which the rivers derive their sources*.

The figure of mountains is likewise very different. Some consist of long chains of nearly an equal height; others are intersected by deep valleys; the contours of some mountains are pretty uniform; those of others are most irregular, and sometimes a detached little mountain appears in the middle of a plain or valley. There are also two kinds of plains; some occupy the low grounds, and others appear in the mountains. The former are generally divided by some large river; but the latter, though their

* See *Lettres Philosophiques sur la Formation des Sels*, &c. p. 198.

extent be considerable, are dry, or furnished with a small rill only. The plains in the mountains are often exceedingly high, always of difficult access, and form one country above another, as in Auvergne, Savoy, and other elevated provinces. The soil of them is firm, and produces plenty of herbs and odoriferous plants, which make them the finest pasture-grounds in the world.

The tops of high mountains are composed of rocks of different elevations, which, when viewed at a distance, make them resemble the waves of the sea *. This is not the only reason for our affirming that mountains were formed by the motions of the sea; I only mention it, because it corresponds with every other phenomenon. But the following facts put this point beyond all controversy: The fossil shells, and other sea-bodies, every where found in such profusion, that they could not possibly be transported from the sea, in its present state, into continents so distant, and deposited at such great depths in the bowels of the mountains: The universal parallelism of the different strata, an effect which could only be produced by water, and the composition even of the most dense of them, as those of stone and marble, which clearly evinces, that, before their formation, they had been reduced into a fine powder, and precipitated to the bottom in the form of sediments:

* See *ibid.* p. 196.

The exactness with which the fossil shells are moulded in the matters in which they are found : The cavities of fossil shells, which are uniformly filled with the same substances that contain them : The corresponding angles of hills and mountains, which nothing could effect but the currents of the ocean : The equality in the heights of opposite hills, and the different strata uniformly appearing at the same levels : And, lastly, the direction of mountains, the chains of which extend longitudinally, like the waves of the sea.

With regard to the depths or hollows on the surface of the earth, those of the ocean are unquestionably the greatest. But, as these are hid from human view, and can only be discovered by sounding, we shall confine ourselves to those which appear on the dry land, such as deep valleys, precipices found between rocks, abysses that present themselves in high mountains, as the abyss of Mount Ararat, the precipices of the Alps, the valleys of the Pyrennees, &c. These depths are a natural consequence of the elevation of mountains ; they receive the water and earth carried down from the high grounds ; their soil is generally fertile ; and they are full of inhabitants. The precipices among rocks are often occasioned by a sudden sinking of one side, the base, which generally inclines more one way than another, being loosened by the action of the air, and of frost, or by the violence of
 torrents.

torrents. But abyſſes, or thoſe enormous precipices that appear on the tops of ſome mountains, and, to the bottom of which, though their circumference be a mile and a half, or three miles round, it is impoſſible to deſcend, have been formed by the operation of fire. They have been the furnaces of ancient volcano's, the matter of which has been exhausted by exploſions, and the long action of fires that are now extinguished by the defect of combuſtible matter. Of this kind is the abyſs of Mount Ararat, deſcribed by Tournefort. It is ſurrounded with rocks which are black and burnt. The abyſſes of Etna and of Veſuvius will have the ſame appearance after their inflammable materials are exhausted.

In Plot's hiſtory of the county of Stafford in England, there is an account of a kind of gulf, which was ſounded by a rope of 2600 feet, without finding either water or bottom, the rope being too ſhort*.

The greateſt cavities, and the deepeſt mines, are generally in the mountains, and ſeldom deſcend to the level of the plains. By them we diſcover the internal ſtructure of the mountain only, not that of the globe itſelf.

Befides, theſe depths are not very conſiderable. Mr. Ray affirms, that the deepeſt mines exceed not half a mile. The mine of Cotteberg, which, in the time of Agricola, was eſteemed to be the

* See Journal des Savans, 1680, p. 12.

deepest in the world, was only 2500 feet of perpendicular depth. There are, indeed, holes in particular places, as that mentioned by Plot, or Pool's hole in the county of Derby, the depth of which is probably very great: But none of them bear any sensible proportion to the thickness of the globe.

If the kings of Egypt, in place of erecting pyramids as monuments of their vanity and riches, had expended equal sums in making profound excavations into the bowels of the earth, to the depth of perhaps a league, they might have discovered substances which would have recompensed their labour; they would at least have extended the knowledge of the earth's internal structure, which might have been productive of much utility.

But, let us return to the mountains. The highest of ~~them~~ ^{lie} between the tropics; and the nearer we approach to the equator, the greater are the inequalities on the earth's surface. A short enumeration of mountains and islands will be sufficient to establish this point.

In America, the Cordeliers, which are the highest mountains in the world, lie precisely under the equator; and they extend on both sides a considerable way beyond the Tropic circles.

The highest mountains of the Moon, of Monomotapa, and the great and little Atlas, in Africa, lie either under or very near the equator.

In Asia, Mount Caucasus, the chain of which, under different names, runs into China, and through this whole extent, lies nearer the equator than the poles.

In Europe, the Pyrennees, the Alps, and the mountains of Greece, which form one chain, are still less distant from the equator than the pole.

These chains of mountains, of which we have given an enumeration, are higher, and of greater extent, both in length and in breadth, than those of more northern countries. With regard to their direction, the Alps form a continued chain which runs across the whole Continent from Spain to China. They commence on the sea-coast of Galicia, join the Pyrennees, traverse France, by Vivares and Auvergne, run through Italy, and stretch into Germany, above Dalmatia, until they reach Macedonia; from thence they join the mountains of Armenia, the Caucasus, the Taurus, the Imaus, and at last terminate on the coast of Tartary. Mount Atlas, in the same manner, traverses the whole Continent of Africa, from the kingdom of Fez to the straits of the Red Sea. The mountains of the Moon have likewise the same direction.

But the mountains of America have an opposite direction. The vast chains of Cordeliers, and other mountains, run more from south to north than from east to west.

What

What we have now remarked concerning the greatest elevations of the land, applies equally to the greatest depths of the sea. The most extensive and deepest seas lie nearer the equator than the poles. From these united observations, the truth of our general position, that the greatest inequalities of the globe are to be found in the equatorial regions, is sufficiently established. These irregularities on the surface of the earth give rise to a number of curious phenomena. Between the Indus and the Ganges, for example, there is a large peninsula, through the middle of which runs a chain of high mountains, called the *Gate*, which extends from north to south, from the extremity of Mount Caucasus to Cape Comorin. One side of this peninsula forms the coast of Malabar, the other that of Coromandel. On the Malabar side, between the chain of mountains and the sea, the season of summer is from September to April; and, during these months, the sky is serene, and no rain falls. But on the Coromandel coast, which lies on the other side of the mountains, this very period is their winter, and the rains fall in torrents. This reverse of summer and winter happens, in some places, no farther distant than 20 leagues; so that, by crossing the mountains, a man has it in his power to change seasons. The same thing, it is said, takes place at Cape Razalgate in Arabia, and even in Jamaica, which is divided from east to west by a chain of mountains. On the south
side

fide of these mountains, the plantations enjoy the warmth of summer, while those on the north suffer all the rigours of winter. Peru, which is situated under the line, and extends about 1000 leagues toward the south, is divided into three long and narrow portions, called by the inhabitants *Lanos*, *Sierras*, and *Andes*. The *Lanos*, which are the plains, extend along the coast of the South sea; the *Sierras* are hills interspersed with valleys; and the *Andes* are the famous *Cordeliers*, the highest mountains of the world. The *Lanos* are about 10 leagues broad; the *Sierras*, in many places, 20 leagues; and the *Andes* nearly the same, though some parts of them are more, and others less broad. The breadth of these divisions is from east to west, and their length from south to north. This part of the world exhibits the following remarkable appearances: 1st, Along the whole coast of the *Lanos*, a south-west wind almost constantly blows, which is contrary to the ordinary direction of the wind in the Torrid Zone. 2d, In the *Lanos*, it never rains or thunders, though there are plenty of dews. 3d, It rains almost continually at the *Andes*. 4th, In the *Sierras*, which lie between the *Lanos* and the *Andes*, it rains from September to April.

It was long thought that all high mountains run from west to east, till the contrary direction was discovered in America. But M. Bourget was the first who remarked the surprising re-

gularity in the structure of these great masses. After passing the Alps thirty times in fourteen different places, the Apennines twice, and making several tours in the neighbourhood of these mountains, and of Mount Jura, he found, that the contours of all mountains have a near resemblance to the works in regular fortifications. When the direction of a mountain is from west to east, all its projections, or advances, stretch to the south and north. This amazing regularity is so remarkable in the valleys, that a man is apt to imagine he is walking in a covered way. If, for example, a man travels in a valley from north to south, he perceives that the mountain which lies to the right hand makes projections to the east, and that the projections of the opposite mountains regard the west, in such a manner, that the prominent and concave angles, on each side, alternately correspond with one another. When the valleys are large, the angles of the mountains are less acute, because they are more distant from each other, and the declivity is not so rapid or steep. These angles are not perceptible in plains, except when we station ourselves on the banks of the rivers, which generally occupy the middle of the plains, and whose natural windings correspond to the most advanced angles or projections of the mountains. It is astonishing that such an obvious fact should have remained so long unnoticed; for, it is apparent, that, in valleys lined

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with opposite mountains, when the declivity of one of the mountains is less rapid than that of the other, the course of the rivers is not in the middle, but nearer to the steepest mountain*.

These general observations might be confirmed by a multitude of facts. The mountains of Switzerland, for example, are steeper on the south side than on the north, and on the west side than on the east. This appearance is obvious in Mount Gemmi, Mount Brisa, and in almost all the other mountains in this country, the highest of which are those which separate Vallesia, and the Grisons of Savoy, from Piedmont and Tirol. These countries are, indeed, a continuation only of the same mountains, the chain of which extends to the Mediterranean; and the Pyrennees are a continuation only of that vast mountain, which commences in Upper Vallesia, whose branches stretch far to the west and south, and preserve, throughout that whole extent, a great height; but, on the north and east sides, they gradually sink into plains, as appears in those extensive countries which are traversed by the Rhine and Danube before they finish their course, while the Rhone descends with rapidity to the south, and empties itself in the Mediterranean. The same observation is exemplified in the mountains of England and of Norway. But the most perfect example is af-

* See *Lettres Philosophiques sur la Formation des Sels*, p. 184. 200.

forded by the mountains of Chili and Peru. The Cordeliers are exceedingly steep on the west side; but they have a gradual declivity to the east, and terminate in vast plains, which are watered by the greatest rivers in the world*.

M. Bourguet, to whom we are indebted for the discovery of the correspondence between the angles of mountains, calls this discovery *the Key to the Theory of the Earth*. However, he appears not to have perceived its whole importance; for, in his treatise on this subject, he gives the skeleton only of an hypothetical system, in which most of his conclusions are either false or uncertain. The theory that we have delivered rests upon four principal facts, the truth of which, after examining the proofs that support them, cannot admit of a doubt: the *first* is, That the earth, to very considerable depths, is every where composed of parallel strata of different matters, which were formerly in a fluid or soft state: the *second*, That the sea has, for many ages, covered the whole earth which we now inhabit: the *third*, That the tides and other motions of the waters, produce inequalities in the bottom of the sea: and the *fourth*, That the figure, and corresponding direction of mountains, have originated from currents in the ocean.

After perusing the proofs contained in the subsequent articles, the reader will be enabled to

See Phil. Trans. Abridg. vol. 6. part 5. p. 178.

determine whether I am right in maintaining, that these facts, when firmly established, will likewise ascertain the general theory of the earth. What has been remarked concerning the formation of mountains needs no farther explanation. But, as it may be objected, that I have not accounted for the formation of peaks, or pointed mountains, nor for some other particular facts, I shall add such observations as have occurred upon this subject.

I have endeavoured to form a distinct and general idea of the manner in which the materials composing this earth are arranged, and have reduced the whole to two classes. The *first* includes all the matters which are disposed in horizontal or regularly inclined beds or strata; and the *second* comprehends all those matters which appear in detached masses, in ridges, or in veins, either perpendicular, or irregularly inclined. In the *first* class I rank sands, clays, granites, flints, and free-stones in large masses, pit-coal, slates, and likewise marls, chalk, calcinable stones, marbles, &c. In the *second*, I include metals, minerals, crystals, precious stones, and flints in small masses. Under these two classes, all the known materials of the earth are comprehended. Those of the first class owe their origin to sediments transported and deposited by the waters of the sea, and ought to be distinguished into such as are calcinable by the application of fire, and such as melt, and are convertible,

convertible into glass. The matters comprehended under the second class are all vitrifiable, with the exception of those called inflammable, or which totally consume in the fire.

There are, in the first class, two distinct species of sand; the one, which abounds more than any other matter in the globe, is vitrifiable, or rather consists of fragments of real glass: The other, which is less in quantity, is calcinable, and ought to be regarded as the dust of stone, and as differing from gravel only by the grossness of its grains. In general, vitrifiable sand lies in beds; but they are frequently interrupted by masses of free-stone, of granite, and of flint; and sometimes these substances appear in banks of a considerable extent.

Sea-shells are seldom found in this sand, or in vitrifiable bodies; and even those which appear in them are not disposed in beds, but scattered, as it were, by chance: I never, for example, found any in free-stone. This stone, which abounds in certain places, is nothing but sand united by a cement. It never appears but in countries where vitrifiable sand is frequent; and the quarries of it are generally in pointed hills, sandy lands, or interrupted eminences. These quarries may be wrought on all sides; and, when they appear in large-beds, they are more distant from each other than those of marble or calcinable stones. Blocks of free-stone may be cut of all dimensions; and, though it be diffi-

cult to work, its hardness is inconsiderable ; for it is easily reduced to sand by friction, except the black points or nails sometimes found in it, which are so hard as to resist the best files. Common rock-stone, which I consider as a species of granite, is vitrifiable, and of a similar nature with free-stone ; it is only harder, and more firmly cemented. It has likewise several dense points, which cut the shoes of travellers on mountainous grounds. It also contains a great number of talky spangles ; and the whole is so hard as not to be worked without great labour.

After narrowly examining these hard points found in free-stone and granite, I discovered that they consist of metallic matter, which has been melted and calcined by a strong fire, and that they have a perfect resemblance to certain substances thrown out of volcano's, of which I have seen vast quantities in Italy. They are called by the inhabitants *Schiarri*. They are black heavy masses, upon which neither fire, water, nor the file, can make any impression. This metallic matter is different from lava, the latter being a species of glass ; but the former seems to partake more of metal than of glass. The points in free-stone and granite have a great resemblance to this matter, which is a farther proof that those substances have formerly been liquified by fire.

On the tops of some high mountains, blocks of granite appear in great quantities. The positions of these blocks are so irregular, that they seem

seem to have been thrown together by accident; and we should be apt to imagine that they had tumbled down from some neighbouring height, if the places where they are found were not higher than any neighbouring ground. But their vitrifiable nature, and their angular and square figures, like those of free-stone rocks, discover these substances to have an uncommon origin. Thus, in large strata of vitrifiable sand, we find blocks of free-stone and granite, the figure and situation of which follow not exactly the horizontal position of strata. The rains have gradually brought down from the hills and mountains the sand with which these blocks were originally covered, by furrowing and cutting into those intervals that appear between the yolks or nuclei in free-stone, in the same manner as the hills of Fontainebleau are intersected. Every point of a hill resembles a nucleus in free-stone quarries, and all the intervals have been scooped out by the rains, and the sand they originally contained has been carried down to the valleys. In the same manner, the angular blocks of granite on the tops of high mountains were formerly covered and surrounded with vitrifiable sand, which, being gradually carried off by the rains, left the blocks in the position in which they happened to be formed. These blocks are generally pointed at the top, and augment in thickness towards their bases; one block often rests upon another, that upon a third, and so on,

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leaving irregular intervals between them† and as, in the course of time, the sand which covered the blocks, and filled the intervals, was washed down by the rains, there would nothing remain on the tops of high mountains but pointed piles of irregular blocks; and hence the origin of peaks, or mountains ending in sharp points.

For, let it be supposed, as may easily be proved by the sea-bodies found in the Alps, that this chain of mountains was formerly covered by the ocean, and that a thick bed of vitrifiable sand was deposited upon their tops, which reduced the whole chain to a level country. This bed of sand would necessarily give rise to large blocks of granite, of free-stone, of flint, and of other bodies, the consistence and figure of which originate from sand, nearly in the same manner as salts crystallize. These blocks, after the sand which covered them, and filled their interstices, was carried down to the plains, by rains, torrents, &c. would maintain their original stations, remain bare on the tops of the mountains, and constitute all those peaks or pointed eminences so frequently exhibited by Nature. To the same origin must be ascribed those high detached rocks which are found in China and other countries, as in Ireland, where they are distinguished by the name of *Devil's stones*, and the formation of which, as well as of peaked mountains, has hitherto appeared so difficult to explain. The explication, however, which I have given, is so natural,

natural, that it generally occurs to every person, who examines these objects; and, on this occasion, I will set down a passage from father Tartre.

‘ From Yanchuin-yen we arrived at Hotcheou. Upon the road we remarked a singular phænomenon, namely, rocks of a surprising height, resembling square towers, in the midst of vast plains. I cannot account for this appearance, unless I be allowed to suppose these rocks to have formerly constituted a part of mountains, and that the earth, sand, and other loose parts, had been gradually washed away by the rains, and left rocks bare on all sides. What fortifies this conjecture is, that we saw some of them, the bases of which were still surrounded with earth to a considerable height*.’

The tops of the highest mountains, often for 200 or 300 fathoms, consist of rocks of granite, free-stone, and other hard and vitrifiable substances: Below these, we frequently meet with quarries of marble, or hard calcinable stone, full of fossil shells; as may be seen at the great Chartreuse in Dauphiny, and upon Mount Cenis, where the stones and marbles which contain shells are situated some hundreds of fathoms below the points or peaks of high mountains, though these beds of stone and marble be more than 1000 fathoms above the level of the sea. Thus those mountains which have peaks or points generally

* See *Lettres Edifiantes*, tome i. p. 135.

consist

consist of vitrifiable rocks; and those, the summits of which are flat, contain, for the most part, marbles, and hard stones full of sea-bodies. The same remark holds with regard to hills; for those composed of granite or free-stone are generally intersected with points, eminences, cavities, and small valleys. But those composed of calcinable stone are nearly of an equal height, and are only interrupted by larger and more regular valleys, with corresponding angles; and they are crowned with rocks, uniform and level in their position.

Though these two species of mountains seem to be very different, their figures have been produced by the same cause, as has already been shown: But, it may be remarked, that the calcinable stones have suffered no change since the original formation of the horizontal strata. The vitrifiable sands, however, may have been changed and interrupted by the subsequent production of rocks and angular blocks which take place in sand-beds. Both species have fissures. Those in calcinable rocks are almost always perpendicular; but those of granite and free-stone are somewhat more irregular in their direction. It is in these fissures that metals, minerals, crystals, sulphur, and all the substances of our second class, are found. Below the fissures, the waters assemble, penetrate the earth, and give rise to the veins of water which every where appear under the surface.

P R O O F S

OF THE

THEORY OF THE EARTH.

ARTICLE X.

Of Rivers.

I HAVE already remarked, that, in general, the greatest mountains occupy the middle of continents; that those of a smaller kind divide islands, peninsulas, and promontories; that, in the Old Continent, the direction of the greatest chains of mountains is from west to east; and that those which run to the north or south are only branches of the principal chains. It will appear on examination, that the greatest rivers have the same direction, and few of them follow the course of the branches of mountains. To be convinced of this fact, we have only to run our eye over a common globe; and, beginning with Spain, we shall find that the Vigo, the Douro,

Douro, the Tagus, and the Guadiana, run from east to west, and the Ebro from west to east; and that there is not a river of any consideration which runs from south to north, or from north to south, although Spain be almost entirely environed by the sea on the northern and southern parts. This remark concerning the rivers of Spain demonstrates, that the direction of the mountains is from west to east; that the southern provinces near the Straits are more elevated than the coast of Portugal; that, in the northern parts, the mountains of Galicia, the Asturias, &c. are a continuation only of the Pyrennees; and that this elevation of the country, both in the south and north, is the cause which prevents the rivers from running to the sea in these directions.

In examining the map of France, it is apparent that the Rhone is the only river which runs from north to south; and, even near one half of its course, from the mountains to Lyons, is from east to west: But the direction of all the great rivers, as the Loire, the Charente, the Garonne, and even the Seine, is from east to west.

The same observation holds with regard to Germany. The Rhine, like the Rhone, has the greatest part of its course from south to north: But the other large rivers, as the Danube, the Elbe, and all the rivers which fall into them, run from west to east, and empty themselves in the Black-Sea.

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The Black Sea, which should rather be regarded as a large lake, is, from east to west, nearly three times as long as from south to north; and consequently its direction is similar to that of the rivers. The same remark is applicable to the Mediterranean, which is nearly six times longer from east to west than from north to south.

The Caspian, it must be acknowledged, according to the chart made by order of the Czar Peter I. extends more from north to south, than from east to west. But the ancient charts represented it as nearly round, or rather as extending more from east to west than in the opposite direction. If, however, the lake Aral be considered as a part of the Caspian, from which it is separated by a sandy plain only, the greatest extent of this sea will still be from west to east.

The course of the Euphrates, of the Persian gulf, and of almost all the rivers of China, is likewise from west to east. The rivers of the interior parts of Africa observe the same direction, running either from west to east, or from east to west. The Nile, and the rivers of Barbary, are the only ones which run from south to north. There are, it is true, large rivers in Asia, as the Don, the Wolga, &c. which partly run from north to south: But they only observe this direction in order to fall into the Black
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and Caspian seas, which are lakes in the interior parts of the country.

We may, therefore, lay it down as a fact, that, in general, the rivers and mediterranean waters of Europe, Asia, and Africa, run or stretch more from east to west than from north to south. This is a natural consequence of the parallel direction of the different chains of mountains. Besides, the whole continent of Europe and of Asia is broader from east to west than from north to south: For the direction of mountains may be considered in two points of view. In a long and narrow continent, like that of South America, which contains only one principal chain of mountains, extending from south to north, the rivers, not being restrained by any parallel chain, must run in channels perpendicular to the range of these mountains, that is, either from east to west, or from west to east; and this, in fact, is the direction of all the great rivers in America. But though, both in the Old and New Continent, the great rivers run in the same direction, this effect is produced by different causes. The rivers, in the Old Continent, run from east to west, because they are confined by many parallel chains of mountains which stretch from west to east; but those of America observe the same direction, because there is only one chain of mountains stretching from south to north.

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The rivers generally occupy the middle of the valleys, or the lowest ground between two opposite hills : If the two hills have nearly an equal declivity, the river runs nearly in the middle between them, whether the intermediate valley be broad or narrow. If, on the contrary, the declivity of one of the hills be greater than that of the other, the river will not occupy the middle of the valley, but will approach to the steepest hill, in proportion to the superiority of its declivity. In this case, the middle of the valley is not the lowest ground between the two hills, but lies much nearer the steepest of them ; and consequently the river must occupy that space. This observation holds universally wherever the difference in declivity is remarkable ; and the rivers never recede from the steepest hills, unless, in their course, they meet with other hills of equal declivity. In process of time, however, the declivity of the steepest hill is diminished by the rains, the melting of snow, &c. The steeper any hill is, it loses greater quantities of earth, sand, and gravel, by the operation of rains, and these substances are carried down into the plain with a proportionably greater rapidity, and, of course, force the river to change its channel, or, in other words, to retire into a lower part of the valley. It may be added, that, as all rivers occasionally swell, and overflow their banks, they carry off mud and sand, which they deposit in different parts

parts of the valley; and, as sand and gravel are often accumulated in the channels themselves, these circumstances make the waters overflow, and alter the direction of their course. Nothing, accordingly, is more common, than to find in valleys many old channels in which the river has formerly run, especially when it is rapid, subject to frequent inundations, and carries down great quantities of sand and mud.

In plains, and extensive valleys, watered by large rivers, the channels of the rivers are commonly the lowest parts. But the surface of the water in the river is sometimes higher than the adjacent ground. When a river, for instance, begins to overflow, it soon covers a considerable part of the plain; but the banks remain longest uncovered by the water. This circumstance plainly shows that the banks of rivers are higher than the neighbouring ground; and that, from the banks to a certain part of the plain, there is a small declivity or slope. When, therefore, the water rises to the margin of the banks, it must be higher than the plain. This elevation of the ground on the banks of rivers is occasioned by mud and sand being deposited in the time of inundations. The water, during great swells, is always exceedingly foul and muddy: When it begins to overflow, it runs slowly over the banks, and, by depositing the mud and sand, it gradually purifies as it advances into the plain: Thus, all the mud, and other substances, which
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are not carried down by the current, are deposited upon the banks, and gradually elevate them above the rest of the plain.

Rivers are always widest at their mouths, and turn gradually narrower towards their sources: But it is more worthy of remark, that, in the interior parts of a country, and at great distances from the sea, their course is straight, and the frequency of their windings increases proportionally as they approach to their termination. I have been informed by M. Fabry, who performed many journeys in the western parts of North America, that travellers, and even the savages, form pretty accurate computations of their distance from the sea, by observing the courses of the rivers. If a river ran straight for 15 or 20 leagues, they knew themselves to be a great way from the coast; but, if the sinuosities were frequent, they concluded that the sea was not very distant. M. Fabry, when travelling through unknown and uninhabited regions, derived much advantage from this observation. Near the sides of great rivers, the regorging of the water is likewise less apparent the farther from the sea, which furnishes another medium of judging concerning the distance: And, as the sinuosities multiply the nearer rivers approach to their mouths, it is not surprising that some of them should yield to the pressure of the water, and give rise to several branches or divisions, before they reach the sea.

The motion of the water in rivers is very different from the representation given of it by mathematicians. The surface, taken from bank to bank, is not level; but the middle of the stream is either higher or lower, according to circumstances, than the water at the sides. When a river swells suddenly by the melting of snow, or any other cause, its rapidity increases; and, if its course be straight, the middle of the stream, where the current is greatest, rises and forms a sensible convexity. This elevation is sometimes very considerable. M. Hupeau, who measured this difference of level between the sides and the stream of the Aveyron, found it to be three feet. This effect must always be produced when the rapidity of the current is great; for the quickness of the motion, by diminishing, or partly preventing the action of gravity, allows not to the water, in the middle of the stream, time sufficient to bring it to a level with that on the sides, and, therefore, it remains higher. On the other hand, near the mouths, though the current be very rapid, the water near the sides is commonly more elevated than that of the middle: The river, in this situation, has a concave form, the lowest point of which is the middle of the stream. This effect is always produced as far as the influence of the tides is perceptible, which, in large rivers, extends sometimes to 100 or 200 leagues from the sea. It is likewise a fact well known, that the streams of rivers

rivers continue their motion a considerable way through the waters of the sea. In this case, the water of the river has two opposite motions. The middle, or current, precipitates itself towards the sea; but the action of the tide produces a counter current, or regorging, which elevates the water on the sides, while that in the middle descends; and, as all the water must be carried down by the current, that on the sides constantly descends towards the middle of the stream, with a quickness proportioned to the elevation it receives from the regorging of the tide.

There are two species of regorging, or damming up, in rivers: The first is that just now described, and is occasioned by the action of the tide, which not only opposes the natural descent of the water, but even communicates to it a contrary motion or current: The other is produced by an inactive cause, as a projection of the land, an island, &c. Though this kind of regorging gives not rise to any extraordinary counter current, it often sensibly retards the progress of small boats, and produces what is called *dead water*, which observes not the natural course of the river, but turns about in such a manner as greatly obstructs the progress of vessels. These dead waters are sensibly felt in passing through the arches of a bridge, especially if the river be rapid. The celerity with which water runs, when the height or pressure is the same, increases in proportion as the diameter of the canal,

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through which it passes, is diminished. The celerity of a river, therefore, in passing through a bridge, increases in the inverse proportion of the width of the whole arches, to the total width of the river. This increase of celerity, in passing through the arch of a bridge, is so considerable, that it pushes the water from the stream towards the banks, from which it is reflected, and sometimes forms violent eddies or whirlpools. In passing under the bridge of St. Esprit, the mariners are obliged scrupulously to keep the stream, even after leaving the bridge; for, if they allowed the boat to decline either to the right or left, it would be driven with violence against the banks, or, at least, would be forced into the whirling or dead waters, from which they would find some difficulty of escaping. When the eddy is considerable, it forms a small gulf with a cylindrical void in the middle, round which the water turns with rapidity. This cylindrical cavity is an effect of the centrifugal force, which makes the water endeavour to fly off from the centre of the whirlpool.

When a great swell of the river is about to happen, the water-men perceive a particular motion, which they call a *moving at the bottom*; that is, when the water at the bottom moves with an unusual velocity, which, according to them, always indicates the approach of a sudden swell. The motion and weight of the superior waters, thought not yet arrived, fail not to act upon the
waters

waters in the inferior parts of the river, and to communicate motion to them: For a river, in some respects, must be considered as a column of water contained in a tube, and its channel as a long canal, in which every motion must be communicated from one end of it to the other. Now, independent of the motion of the superior waters, their weight alone may increase the celerity of the river, and perhaps make it move quickest at the bottom; for it is well known, that, when several boats are at once pushed into a river, they increase the motion of the water below, and retard that of the superior water.

The celerity of running waters is not in exact proportion to the declivity of their channels. A river with a uniform declivity, and double to that of another, ought not, it would appear, to run with more than a double celerity: But its celerity is much more quick, being sometimes triple, sometimes quadruple, &c. The celerity depends more upon the quantity of water, and the weight of the superior waters, than upon the degree of descent. In digging the bed of a river or drain, it is unnecessary to make the descent uniform through its whole extent. A quick motion is more easily produced by making the declivity much greater at the source than at the mouth, where, like the beds of natural rivers, it is almost imperceptible, and yet they preserve their celerity, which is more or less, according to the quantity they contain; for

in great rivers, even where the ground is level, the water still runs, not only with the velocity originally acquired, but with the accumulated velocity produced by the action and weight of the superior waters*. To make this matter still more plain, let us suppose the Seine from Pont-neuf to Pont-royal to be perfectly level, and to be ten feet deep; let us also suppose the bed of the river below Pont-royal and above Pont-neuf to be suddenly dried up; the waters, in this case, would run both up and down the channel, till their equilibrium was perfectly restored. This effect is produced solely by the weight of the water, which never allows it to remain at rest till its particles are equally pressed on all sides, and its surface reduced to a perfect level. The weight of water, therefore, contributes greatly to increase the celerity of its motion. This is the reason why the greatest celerity in a current of water is neither at the bottom nor at the surface, but nearly in the middle, which is pressed both by the column above, and by the reaction from the bottom. But, what is still more, when a river acquires a great celerity, it will not only preserve it, though running through a level country, but even surmount heights, without

* By not attending to these circumstances, M. Khun was led falsely to affirm, that the source of the Danube was at least two German miles higher than its mouth; that the Mediterranean is $6\frac{1}{2}$ German miles lower than the sources of the Nile; that the Atlantic ocean is half a mile lower than the Mediterranean, &c.

spreading

spreading much to a side, or, at least, without producing an inundation of any moment.

One would be apt to imagine, that bridges, and other obstacles erected in rivers, would create a considerable diminution of celerity in their whole course. But the difference is very small. The water, upon meeting with any obstacle, rises, in order to surmount it; and the increase of celerity communicated by its fall, nearly compensates the retardation occasioned by the obstacle. Thus, sinuosities, projections from the land, and islands, create but a small variation on the total celerity of a river's course. The most considerable alterations are produced by the greater or lesser quantities of water; when the quantity is small, a river runs slow, when great, it runs with rapidity.

If rivers were always equally full, to enlarge their channels would be the best method of diminishing their rapidity, and to contain them within their banks. But, as almost all rivers rise and fall, it is more necessary, for this latter purpose, to narrow their channels; for small waters, with large channels, generally scoop out winding beds in the middle; and, when they swell, they follow the direction of these particular beds, and by striking with violence against the banks, often do much injury to mills and other works. These bad effects might be prevented, by digging gulfs in the earth at convenient distances. To accomplish this purpose, a

part of one of the banks should be cut through, and the earth removed for a considerable space. These small gulfs should be made in the obtuse angles of the river; for the water, in turning, would run into them; and, of course, its celerity would be diminished. This method might be useful in preventing the fall of bridges in places where sufficient barriers cannot be erected to resist the weight of the water,

The manner in which inundations are produced, merits particular attention. When a river swells, its celerity uniformly increases, till it begins to overflow the banks: From that moment its rapidity is checked, which is the reason why inundations always continue several days; for, though the quantity of water should be diminished after the commencement of the inundation, it would, notwithstanding, continue to overflow; because this circumstance depends more on the celerity than on the quantity of water. If it were otherwise, rivers would often overflow their banks for an hour or two, and then retire to their channels, which never happens. An inundation, on the contrary, always lasts some days, although the rains have ceased, and less water runs in the river; because the overflowing of waters diminishes their celerity; and, consequently, although the same quantity of water arrives not in the same time as formerly, the effect is the same as if a larger quantity had been brought down. It may likewise

wife be here remarked, that, if a high wind blows contrary to the current of the river, the inundation will be increased by this occasional cause, which diminishes the celerity of the water; but, if the wind blows in the direction of the current, the inundation will be less, and retire more quickly.

‘ The inundation of the Nile,’ says M. Granger, ‘ has long been a subject of discussion among the learned. Most of them have considered it as a singular and wonderful phenomenon, though nothing be more natural or more common; for it takes place in every country, as well as in Egypt. The inundation of the Nile is occasioned by the rains which fall in Ethiopia and Abyssinia; but the north wind may be regarded as the principal cause of it: 1. Because the north wind drives the clouds which contain this rain into Abyssinia: 2. Because it prevents the water from running out of the mouths of the river in any great quantity, by damming up the stream. The great effect of this wind may be remarked every season; for, when it changes from north, the Nile loses more water in one day than in four.’

Inundations are generally greatest in the superior parts of rivers; because, as formerly observed, the velocity of a river uniformly increases till it empties itself in the ocean. Father Castelli, a sensible writer on this subject, remarks, that the banks, raised for the purpose of keeping

keeping the Po from overflowing, gradually diminish in height, as the river approaches to the sea; that, at Ferrara, which is 60 or 70 miles from the mouth of the river, the banks are about 20 feet above the ordinary level of the water; but that, at 10 or 12 miles from the sea, though the channel be equally narrow as at Ferrara, they are not above 12 feet*.

In fine, the theory of running waters is subject to many difficulties. It is not easy to give general rules which will apply to every particular case. For this purpose, experience is preferable to speculation: It is not enough that we know the common effects of rivers in general; but, if we would reason justly, and give stability to our labours, we ought to study the peculiarities of particular rivers in which we have an interest. Though the remarks I have made be generally new, a greater collection is necessary. Perhaps we shall in time acquire a distinct knowledge of this subject, and be enabled to give certain rules for directing and confining rivers in such a manner as will prevent the destruction of bridges, banks, and other damages occasioned by the impetuosity of the waters.

The greatest rivers of Europe are, the Wolga, the course of which, from Reschow to Astracan on the Caspian Sea, is about 650 leagues; the Danube, which runs about 450 leagues,

* See Racolta d'autori che trattano del moto dell'acqua, vol. i. p. 125.

from,

from the mountains of Switzerland to the Black Sea; the Don, the course of which, from the source of the Sofna, which receives it, to the Black Sea, is 400 leagues; the Nieper, which likewise falls into the Black Sea, after running 350 leagues; the Duine, which empties itself in the White Sea, runs a course of about 300 leagues, &c.

The greatest rivers of Asia are the Hoanho, in China, which rises at Raja-Ribron, and after running 850 leagues, falls into the middle of the gulf of Changi, in the Chinese sea; the Jenica, which runs from Lake Selinga to the northern sea of Tartary, a course of about 800 leagues; the Oby, the course of which, from Lake Kila to the north sea beyond Waigat's Straits, is about 600 leagues; the river Amour, in east Tartary, has a course of 575 leagues, from the head of the river Kerlon, which falls into it, to the sea of Kamtschatka; the river Menancon may be measured from the source of the Longmu, which falls into it, to its mouth at Poulo-condor; the Kian, the course of which is about 550 leagues, from the source of the Kinxa, which it receives, to its termination in the sea of China; the Ganges, which has a course nearly of the same extent with the Kian; the Euphrates, computing from the source of the Irma, which it receives, runs about 500 leagues; the Indus, which runs about 400 leagues, and falls into the Arabian sea on the east of Guzarat;

rat ; and the Sirderoias, which runs about 400 leagues, and falls into Lake Aral.

The greatest rivers of Africa are, the Senegal, the course of which, comprehending the Niger, which is a continuation of it, and the source of the Gombarou, which falls into the Niger, is about 1125 leagues ; the Nile, which rises in Upper Ethiopia, runs about 970 leagues. There are others, the courses of which are but partially known, as the Zaira, the Coanza, the Couama, and the Quilmanci, each of which we are acquainted with to the extent of 400 leagues.

Lastly, in America, the river of the Amazons runs more than 1200 leagues, if we reckon from the lake near Guanuco, 30 leagues from Lima, where the Maragnon rises ; or, even computing from the source of the river Napo, near Quito, the course of the Amazons is more than 1000 leagues*.

The course of the river St. Lawrence in Canada is more than 900 leagues, computing from its mouth to Lake Ontario, from that to Lake Huron, Lake Superior, Lake Alemipigo, Lake Christinaux, and the lake of the Affiniboils, the waters of all which fall into one another, and at last into the river St. Lawrence.

The river Mississippi runs more than 700 leagues, from its mouth to any of its sources, which are not far from the lake of the Affiniboils.

* See Voyage de Condamine, p. 15.

The river Plata extends more than 800 leagues, from its mouth to the source of the Parana, which it receives.

The river Oronoko runs more than 575 leagues, reckoning from the source of the river Caketa, near Pasto, which partly falls into the Oronoko, and partly runs towards the river of the Amazons*.

The Madera, which falls into the Amazons, extends more than 660 leagues.

In order to compute the quantity of water discharged into the sea by all the rivers, we shall suppose, which is nearly the truth, that one half of the earth's surface is sea, and the other half dry land: We shall likewise suppose the mean depth of the sea to be about 230 fathoms. The total surface of the earth is 170981012 square miles, and that of the sea is 85490506 square miles, which being multiplied by 1-fourth, the depth of the sea, gives 21372626 cubic miles for the quantity of water contained in the whole ocean. Now, to compute the quantity discharged into the ocean by the rivers, let us take a river, the velocity and quantity of whose waters are known; the Po, for example, which passes through Lombardy, and waters a country of 380 miles in length. According to Riccioli, the breadth of the Po, before it divides into branches, is 100 perches of Boulogne, or 1000 feet; and its depth is 10 feet; and it runs at the rate of 4 miles in an

* See M. Condamine's Map.

hour :

hour : Consequently the Po discharges into the sea 200,000 cubical perches of water in an hour, or 4,800,000 in a day. But a cubic mile contains 125,000,000 cubic perches ; of course, it will require 26 days to discharge into the sea a cubic mile of water. It only remains to determine the proportion that the Po bears to all the rivers of the earth taken together, which cannot be done exactly. But, to approach nearly to the truth, let us suppose that the quantity of water which the sea receives from the great rivers in every country, is proportioned to the extent of the surfaces of these countries ; and, consequently, that the country watered by the Po, and by the rivers which fall into it, is to the total surface of the dry land as the Po is to all the rivers of the earth. Now, by the most exact charts, it appears that the Po, from its origin to its mouth, traverses a country of 380 miles in length ; and the rivers which fall into it on each side arise from sources which are about 60 miles distant from the Po. Thus, the Po, and the rivers it receives, water a country 380 miles long, and 120 broad, which makes 45600 square miles. But the surface of the dry land is 85490506 square miles ; consequently, the quantity of water carried to the sea by all the rivers will be 1874 times greater than the quantity discharged by the Po. But, as 26 rivers, equal to the Po, furnish a cubic mile of water each day, it follows, that, in the space of a year,

1874

1874 rivers equal to the Po, will carry to the sea 26308 cubic miles of water; and that in 812 years, all these rivers would discharge 21372626 cubic miles, which is a quantity equal to what is contained in the ocean; of course, if the ocean were empty, 812 years would be necessary to fill it by the rivers*.

It is a result of this calculation, that the quantity of water raised from the sea by evaporation, and transported upon land by the winds, is from 20 to 21 inches in the year, or about $\frac{2}{3}$ of a French line each day. This evaporation, though tripled to make allowance for what falls back into the sea from the clouds, is very inconsiderable. Mr. Halley † has clearly demonstrated, that the vapours transported from the sea, and discharged upon the land, are sufficient to maintain all the rivers and lakes in the world.

After the Nile, the Jordan is the largest river in the Levant, or even in Barbary. It discharges each day into the Dead Sea about 6,000,000 of tons. All this water, and more, is carried off by evaporation; for, according to Halley's calculation of 6914 tons evaporated from each superficial mile, the Dead Sea, which is 72 miles long, and 18 broad, must lose every day, by evaporation, near 9,000,000 of tons; that is, not only all the water it receives from the Jordan, but from the smaller rivers which come

* See Keil's Examination of Burnet's Theory, p. 126.

† See Phil. Trans. num. 192.

from

from the mountains of Moab, and elsewhere. Of course, this sea has no occasion to communicate with any other by subterraneous passages*.

The most rapid of all rivers are, the Tigris, the Indus, the Danube, the Yrtis in Siberia, the Malmistra in Cilicia, &c †. But, as was formerly remarked, the velocity of rivers depends both on the declivity and the weight of water. In examining the globe, we find that the Danube has less declivity than the Po, the Rhine, or the Rhone; for the course of the Danube is longer, and it falls into the Black Sea, which is higher than the Mediterranean, and perhaps than the ocean.

Great rivers, in their course, are constantly receiving small ones into their channels. The Danube, for example, receives more than 200 brooks and rivulets. But if we reckon only rivers of some consideration, we will find, that the Danube receives 30 or 31, the Wolga 32 or 33, the Don 5 or 6, the Nieper 19 or 20, the Duine 11 or 12. The Hoanho, in Asia, receives 34 or 35 rivers, the Jenisca more than 60, the Oby an equal number, the Amour about 40, the Kian, or river Nankin, 30, the Ganges more than 20, the Euphrates 10 or 11, &c. In Africa, the Senegal receives more than 20 rivers; the Nile receives none lower than 500 leagues from its mouth, the last which falls into it being the Moraba; and from this place to its

* See Shaw's Travels.

† See Varenii Geog. p. 178.

source, it receives about 12 or 13. In America, the Amazons receives more than 60 considerable rivers, St. Lawrence about 40, reckoning those which fall into the lakes, the Mississippi more than 40, the Plata above 50, &c.

Upon the surface of the earth, there are elevated countries which seem to be points of partition marked out by nature for the distribution of the waters. In Europe, one of these points is Mont Saint-Godard, and its environs. Another point is the country situated between the provinces of Belozera and Wologda in Muscovy, from which many rivers descend, some into the White Sea, some into the Black, and others into the Caspian. In Asia, there are several points of partition, as the country of the Mogul Tartars, some of whose rivers run into the sea of Nova Zembla, others into the gulf of Linchidolin, others into the sea of Corea, and others into that of China; and the Lesser Thibet, the rivers of which run into the Chinese sea, into the gulf of Bengal, the gulf of Cambaia, and the Lake Aral. The province of Quito, in America, discharges its rivers into the south and north seas, and into the gulf of Mexico.

In the Old Continent, there are about 430 rivers which directly fall either into the Ocean, or into the Mediterranean and Black Seas. But, in the New Continent, we know of only 135 rivers which fall immediately into the sea. In

this number I have reckoned none which are not as large as the river Somme in Picardy.

All these rivers transport, from the countries through which they pass, into the sea, great quantities of mineral and saline particles. The particles of salt, which dissolve in water, are easily carried down to the sea. Several philosophers, and particularly Halley, have alledged, that the saltness of the sea proceeds alone from the particles of salt transported by the rivers: Others maintain, that this saltness was coeval with the sea itself, and that the salt was created to prevent the waters from corrupting. But the agitation of the sea by the winds and the tides is, I imagine, a cause equally powerful as the salt in preserving it against putrification; for, when barrelled up, it corrupts in a few days. And Boyle informs us of a navigator who was overtaken with a calm which lasted 3 days, and who assured him, that the water became so putrid, that, if the calm had continued much longer, the whole crew would have perished*. Sea-water is also impregnated with a bituminous oil, which renders it both unwholesome and disagreeable to the taste. The quantity of salt in sea-water is about a fortieth part, and it is nearly of an equal saltness at the surface and at the bottom, under the Line and at the Cape of Good Hope; though there are some particular places, as off the Mosambique coast, where it is more salt than

* See Boyle, vol. iii. p. 222.

in others*. It is likewise said to be less salt within the Arctic circle: But this phænomenon may proceed from the immense quantities of snow, and the large rivers which fall into these seas, and from the proportional defect of evaporation.

However this matter stands, I believe, that the saltness of the ocean is not only occasioned by the many banks of salt at the bottom of the sea, and along the coasts, but likewise by the salts continually brought down by the rivers; that Halley was right in his conjecture that there was originally little or no salt in the sea, but that its saltness gradually augmented in proportion as salt was supplied by the rivers; that the degree of saltness is perpetually increasing; and, consequently, that, by computing the total quantity of salt carried down by the rivers, we might be enabled to discover the real age of the world. Mr. Boyle affirms, on the authority of divers and pearl-fishers, that the water is colder in proportion to its depth; and that, at great depths, the cold becomes so excessive as to oblige them to come up much sooner than usual. But the weight of the water may be as much the cause of their uneasiness as the intenseness of the cold, especially when they descend 300 or 400 fathom. Divers, however, seldom go deeper than 100 feet. The same author relates, that, in a voyage to the East Indies, when they ar-

* See Boyle, vol. iii. p. 217.

rived at the 35th degree of south latitude, they founded to the depth of 400 fathoms, and when the lead, which weighed about 30 pounds, was drawn up, it had become as cold as ice. It is likewise a common practice at sea to sink the bottles several fathoms, in order to cool their wine; and it is said, that the deeper the bottles are sunk, the wine becomes the cooler.

These facts would lead us to imagine, that the sea-water was saltier at the bottom than at the surface. But they are opposed by facts of a contrary nature: Experiments have been made with vessels which opened only at a certain depth, and the water was not found to be saltier than that at the surface: There are even examples of the water at the bottom being fresher than at the surface: This phænomenon is exhibited in all those places where springs arise from the bottom of the sea, as near Gba, at Ormus, and in the sea of Naples, in which there are many warm springs.

In other places, sulphureous springs and beds of bitumen have been discovered at the bottom of the sea; and, upon land, there are numerous springs of bitumen which run into the sea. At Barbadoes, there is a fountain of bitumen which runs from the rocks into the sea. Bitumen and salt, then, are the principal ingredients in sea-water. But it is blended with many other substances; for its taste differs considerably in different parts of the ocean: Besides, agitation and the

the heat of the sun change the natural taste of sea-water ; and the different colours of different seas, and even of the same sea at different times, prove it to be mixed with many heterogeneous bodies, which are detached either from the bottom, or carried down by the rivers.

Most countries that are furnished with large rivers are subject to periodical inundations ; and those rivers which have long courses overflow with the greatest regularity. Every body has heard of the inundations of the Nile, the waters of which, though spread over a large track of country, and at a great distance from the sea, preserve their sweetness and transparency. Strabo and other ancient authors tell us, that the Nile had seven mouths ; but now only two which are navigable remain : A third canal, indeed, supplies the cisterns of Alexandria ; and there is a fourth, which is still less considerable. As the cleaning of these canals has long been neglected, they are mostly in ruins. In these works the ancients employed annually a vast number of workmen and soldiers, who carried off the mud and sand which this river brings down in great quantities. The overflowing of the Nile is occasioned by the rains which fall in Ethiopia : They begin in April, and end not till September. During the first three months, the days are serene and beautiful ; but the sun no sooner sets, than the rains begin, continue incessantly till sunrise, and are commonly accompanied with

8 2

thunder

thunder and lightning. The inundation in Egypt begins about the 17th of June; it generally takes 40 days in swelling, and as many in subsiding. The whole flat country of Egypt is overflowed: But the inundation is not now so great as in ancient times; for Herodotus affirms, that the Nile swelled 100 days, and required an equal time to subside. If this fact be true, the difference can be ascribed to no other causes but the gradual elevation of the land by the mud brought down and deposited, and the diminution in the height of the mountains from which this river derives its source. It is natural to think, that the height of the mountains is diminished; for the heavy rains that fall in these regions during one half of the year, bring down great quantities of sand and earth from the tops of the mountains into the valleys, from which they are transported by torrents into the channel of the Nile, and are partly deposited on the land by the inundations.

The Nile is not the only river that has regular and annual overflowings: The Pegu, which is equally regular in its inundations, has, from this circumstance, got the name of the *Indian Nile*. It overflows the country for 30 leagues beyond its banks, and, like the Nile, leaves great quantities of mud and slime, which enrich the ground so much, that it produces excellent pasture for cattle, and enables the inhabitants to export

export rice*. The Niger, or, which is the same thing, the upper part of the Senegal, overflows and covers the whole flat country of Nigritia. Its inundations, like those of the Nile, begin about the middle of June, and increase for 40 days. The Plata, in Brasil, overflows annually, and at the same time with the Nile. The Ganges, the Indus, the Euphrates, and some other rivers, produce annual inundations. But all rivers are not subject to periodic inundations: These proceed from a combination of causes, which, at the same time, augment the quantity of water, and diminish its velocity.

We formerly remarked, that the declivity of rivers gradually diminish till they arrive at the sea. But, in some places, the declivity is more sudden, and forms what is called *a cataract*, which is nothing more than an unusually rapid fall of the water. In the Rhine, for example, there are two cataracts, one at Bilefeld, and the other near Schafhouse. The Nile has several cataracts: Two of the most remarkable fall from a great height between two mountains. In the Wologda, in Muscovy, there are also two, near Ladoga. The Zaire, a river in Congo, commences with a large cataract, which falls from the top of a mountain. But the most celebrated cataract is that of the river Niagara in Canada: It falls, in a prodigious torrent, 156 feet of perpendicular height, and is a fourth part of

* See Les Voyages d'Ovington, tom. ii. p. 290.

a league in breadth. The vapour of the water rises to the clouds, is seen at the distance of five leagues, and, when the sun shines above it, exhibits a beautiful rainbow. Below this cataract, the whirlpools and commotions of the waters are so tremendous, as to render navigation impracticable for six miles: and immediately above the cataract, the river is much narrower than higher up*. Charlevoix† describes it in the following manner:

‘ My first care, after my arrival, was to visit
 ‘ the noblest cascade, perhaps, in the world; but
 ‘ I presently found the Baron de la Hontan had
 ‘ committed such a mistake with respect to its
 ‘ height and figure, as to create a suspicion that
 ‘ he had never seen it. If, however, you mea-
 ‘ sure its height by that of the three mountains
 ‘ you are obliged to climb to get at it, it does
 ‘ not fall much short of what the map of M.
 ‘ Deslisle makes it, that is, 600 feet. He has
 ‘ probably adopted this paradox, either on the
 ‘ faith of the Baron de la Hontan, or of Father
 ‘ Hennepin. But, after I arrived at the summit
 ‘ of the third mountain, I observed, that, in the
 ‘ space of three leagues, which I had to walk
 ‘ before I came to this piece of water, though
 ‘ you are sometimes obliged to ascend, you must
 ‘ yet descend still more; a circumstance to which
 ‘ travellers seem not to have sufficiently attend-
 ‘ ed. As it is impossible to approach it but on

* See Phil. Trans. Abridg. vol. vi. part ii. p. 119.

† Tom. iii. p. 353.

‘ one side, and consequently to see it, except in
‘ profile, it is no easy matter to measure its
‘ height with instruments. It has, however,
‘ been attempted by means of a pole tied to a
‘ long line, and, after many trials, it has been
‘ found to be only 115, or 120 feet high. But
‘ it is impossible to be sure that the pole has not
‘ been stopt by some projecting rock; for,
‘ though it was always drawn up wet, as well
‘ as the end of the line to which it was tied,
‘ this circumstance proves nothing, as the water
‘ which precipitates itself from the mountain,
‘ rises very high in foam. For my own part,
‘ after having examined it on all sides, where it
‘ could be viewed to the greatest advantage, I
‘ am inclined to think that we cannot allow it
‘ to be less than a hundred and forty or fifty
‘ feet high.

‘ As to its figure, it resembles that of a horse-
‘ shoe, and is about 400 paces in circumference.
‘ It is divided into two, exactly in the middle,
‘ by a very narrow island, half a quarter of a
‘ league long. It is true, these two parts very
‘ soon unite; that on my side, and which I
‘ could have a side view of only, has several
‘ branches which project from the body of the
‘ cascade, but that which I viewed in front, ap-
‘ peared to me quite entire. The Baron de la
‘ Hontan mentions a torrent, coming from the
‘ west, which, if this author has not invented it,
‘ must certainly fall through some channel dur-
‘ ing the melting of the snows only.’

Three

Three leagues from Albany, in the province of New York, there is a cataract of 50 feet perpendicular height, the vapour of which likewise gives rise to a rainbow*.

In every country where the number of men is too inconsiderable for forming and supporting polished societies, the surface of the earth is more unequal and rugged, and the channels of rivers are more extended, irregular, and often interrupted by cataracts. The Rhone and the Loire would require the operation of several ages before they became navigable. It is by confining and directing the waters, and clearing the bottoms of rivers, that they acquire a fixed and determinate course. In thinly inhabited regions, nature is always rude, and sometimes deformed.

Some rivers lose themselves in the sands, and others seem to precipitate into the bowels of the earth. The Guadalquiver in Spain, the river of Gottenburg in Sweden, and even the Rhine, disappear under ground. It is affirmed, that, in the west part of the Island of St. Domingo, there is a pretty high mountain, at the foot of which are several large caverns that receive the rivers and brooks; and the noise of their fall is heard at the distance of seven or eight leagues†. The number of rivers, however, which disappear in the earth, is very small; and they seem not to

* See Phil. Transf. Abridg. vol. vi. part ii. p. 119.

† See Varen. Geogr. p. 43.

descend very deep. It is more probable, that, like the Rhine, they lose themselves by dividing and dispersing through a large surface of sand, which is very common with those small rivers that run through dry and sandy ground, of which there are many examples in Africa, Persia, Arabia, &c.

The rivers of the north carry down to the sea prodigious quantities of ice, which, by accumulating, form those enormous masses, so dangerous to the mariner. . The straits of Waigat, which is frozen during the greatest part of the year, is most remarkable for these masses of ice, that are constantly brought into the straits by the river Oby. They attach themselves all along the coasts, and rise to great heights. The middle of the strait freezes last, and the ice, of course, does not rise so high as on each side. When the north wind ceases, and it blows in the direction of the straits, the ice begins to melt and to break in the middle; then large masses are detached and transported into the open sea.

• The wind, which blows during the whole winter from the north, over the frozen country of Nova Zembla, renders the regions watered by the Oby, and all Siberia, so cold, that, at Tobolski, in the 57th degree, there are no fruit trees, though at Stockholm in Sweden, and even in higher latitudes, they have fruit trees and leguminous plants. This difference proceeds not, as has been imagined, from the sea of Lapland being

being colder than that of the straits, nor from the country of Nova Zembla being colder than that of Lapland, but from this circumstance alone, that the Baltic and the sea of Bothnia soften the rigour of the north wind; whereas, in Siberia, there is nothing to check its activity. This solution is a result of experience. The cold is never so intense near the sea-coasts as in the interior parts of a country. There are plants which endure the open air all winter at London, which cannot be preserved at Paris: and Siberia, which is a vast continent, is, for this reason, colder than Sweden, which is almost surrounded with the sea.

Spitzbergen is the coldest country in the world: It runs as far as the 78th degree of north latitude, and is composed of small, pointed mountains. These mountains consist of gravel, and of flat stones, like gray slate, heaped upon one another. According to the accounts of voyagers, these hills are raised by the winds, and new ones appear every season. In this country no quadrupeds live but the rein deer, which feeds upon moss. Beyond these hills, and above a league from the sea, the mast of a ship was lately found with a pulley fixed to one end of it; from which circumstances, it has been concluded, that this is a new country, and that it was formerly covered with the sea: It is uninhabited and uninhabitable; for the hills have no consistence, but are loose and moveable; and

a vapour proceeds from the earth, so cold and penetrating, as to preclude the possibility of remaining any time upon this dreary and inhospitable land.

The whale-fishing vessels arrive at Spitzbergen in July, and depart from it about the middle of August. The ice permits them not to arrive sooner, or to remain longer. In these seas there are prodigious boards of ice, clear and shining as glass, and from 60 to 80 fathoms thick; and, in some places the sea appears to be frozen to the bottom.*.

The seas of North America are likewise much infested with ice, as in Ascension-bay, in Hudson's, Cumberland's, Davis's, and Frobisher's straits, &c. We are assured by Robert Lade, that the mountains of Friesland are entirely covered with snow; and that the ice surrounds the coasts, and, like a bulwark, prevents all approach to them. 'It is remarkable,' says he, 'that, in this sea, we meet with islands of ice, more than half a league in circumference, exceedingly high, and descend from 70 to 80 fathoms deep. This ice, which is sweet, is perhaps originally formed in the rivers or straits of the adjacent lands, &c. These islands or mountains of ice are moveable, and, in storms, they follow the tract of a ship, as if they were drawn after her by a rope. Some of them

* See recueil des voyages du Nord, tom. i. p. 154.

‘ rise so high above water, that they surmount
 ‘ the tops of the tallest masts*,’ &c.

In the voyages collected for the use of the Dutch East India Company, we have the following account of the ice off Nova Zembla ;

‘ At Cape Troost, the weather was so foggy, as
 ‘ to oblige us to moor our vessel to a bank of
 ‘ ice, which was 36 fathoms below, and 16
 ‘ above the surface of the water. On the 10th
 ‘ of August, the ice began to separate, and to
 ‘ float; we then remarked, that the mass to
 ‘ which our vessel had been moored, touched
 ‘ the bottom; for, though the others were all
 ‘ in motion, and struck against it, and against
 ‘ each other, it remained immovable. We
 ‘ were now afraid of being frozen in, or dashed
 ‘ to pieces; we, therefore, endeavoured to escape
 ‘ from this latitude, though the vessel, in
 ‘ her course, was obliged to push through the
 ‘ ice, which made a great noise round us for
 ‘ a considerable distance: we at last anchored
 ‘ along another board of ice, where we remain-
 ‘ ed that night.

‘ During the first watch, the ice began to
 ‘ split, with an inconceivable noise. The ship’s
 ‘ head kept so strongly to the current in which
 ‘ the ice-boards floated, that we were obliged to
 ‘ veer the cable in order to get her off. We
 ‘ counted above 400 blocks of ice, which sank

* See Lade’s voyages.

‘ 10 fathoms below the water, and appeared to
‘ rise about two fathoms above it.

‘ We then moored the vessel to another block
‘ of ice, which was immersed below the surface
‘ about six fathoms. At a little distance from
‘ this station we perceived a large bank, which
‘ was pointed like a cone, and reached to the
‘ bottom of the sea: we approached it, and
‘ found it to be 20 fathoms below, and about
‘ 12 above the surface of the water.

‘ On the 11th, we sailed up to another bank,
‘ which was 18 fathoms below the surface, and
‘ 10 fathoms above it.

‘ The Dutch, on the 21st, advanced a great
‘ way between the boards of ice, and anchored
‘ during the night. Next morning they retired,
‘ and moored to a bank which was 18 fathoms
‘ below, and 10 above the water. They climbed
‘ to the top, and remarked, as a singular phæ-
‘ nomenon, that it was covered with earth, and
‘ that they found there about 40 eggs. Its co-
‘ lour was a fine azure blue, and totally differ-
‘ ent from that of the other masses. This cir-
‘ cumstance gave rise to various speculations;
‘ some imagining it to be an effect of the ice,
‘ and others thought the whole was a mass of
‘ frozen earth*.’

Wafer met with many floating pieces of ice,
off Terra del Fuego, which were so large that

* See *Troisième voyage des Hollandois par le Nord*, tom.
i. p. 46.

he at first imagined them to be islands: some of them, he remarks, appeared to be a league or two in length, and the largest of them seemed to rise 400 or 500 feet above the surface of the water.

All these boards of ice, as I have remarked in the 6th Article, are transported from the rivers into the sea. Those in the sea of Nova Zembla and in the Straits of Waigat, come from the Oby, and, perhaps, from the Jenisca, and other great rivers in Siberia and Tartary; those of the Hudson's Straits, from Ascension-bay, into which many rivers in North America empty themselves; and those of Terra del Fuego, from the southern continent. If fewer of them appear in the northern coasts of Lapland than in those of Siberia and Waigat's Straits, it is because all the Lapland rivers fall into the gulf of Bothnia, and none of them into the north sea. They may likewise be formed in straits, where the tides rise higher than in the open sea; and, consequently, where the boards of ice which float on the surface may accumulate and produce masses or banks of several fathoms high. But, with regard to those which rise to the height of four or five hundred feet, it appears, that they can no where be produced but near very elevated coasts; and I imagine, that, when the snows which cover these coasts melt; the water runs down upon the boards of ice, and, by freezing anew, gradually augments their
size,

size, till they arrive at this amazing height ; that, in a warm summer, the action of the winds, the agitation of the sea, and perhaps their own weight, may detach them from the coasts, and set them adrift ; and that they may even be transported into temperate climates before they are entirely dissolved.

P R O O F S

OF THE

THEORY OF THE EARTH.

A R T I C L E XI.

Of Seas and Lakes.

THE dry land is every where surrounded by the ocean ; it penetrates, sometimes by large openings, and sometimes by small straits, into the interior parts of different countries, and forms mediterranean seas, some of which are affected by the motion of the tides, and others not. We shall, in this article, trace the ocean through all its windings ; and, at the same time, give an enumeration of the mediterranean seas, which we shall endeavour to distinguish from what are called bays or gulfs, and lakes.

The sea that washes the western coasts of France, forms a gulf between Spain and Britany. This gulf is, by navigators, called the Bay
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of Biscay: It is very open, and advances farthest into the land between Bayonne and St. Sebastian. It likewise advances considerably at Rochelle and Rochefort. This bay begins at Cape Ortegal, and terminates at Brest, where a strait commences between the south point of Brittany and the Lizard Point. This strait, which is at first pretty wide, forms a small bay on the coast of Normandy, the most advanced point of which is at Auranche. It continues pretty large till it arrives at the channel of Calais, where it is very narrow; it then suddenly enlarges, and terminates between the Texel and the coast of Norwich: At the Texel, it forms a small shallow mediterranean called *Zuidersee*, and several large gaps or advances, the waters of which are not of a considerable depth.

After this, the ocean forms a large bay called the *German Sea*, which commences at the northmost point of Scotland, and runs along the east coast of Britain the length of Norwich; and from thence to the Texel, along the coasts of Holland and Germany, of Jutland and Norway, as far as Bergen. This bay may even be considered as a mediterranean; for the Orkney islands nearly shut up its mouth, and seem, by their direction, to be a continuation of the mountains of Norway. It forms a large strait, which commences at the south point of Norway, and continues pretty broad to the island of Zetland, where it suddenly contracts, and forms, between

the coasts of Sweden and the islands of Denmark and Jutland, four small straits; after which, it widens to a small bay, the most advanced point of which is at Lubec; from thence, to the south extremity of Sweden, it continues pretty broad; then it enlarges more and more, and forms the Baltic, which is a mediterranean sea, extending, from south to north, near 300 leagues, if the gulf of Bothnia, which is a continuation of it, be comprehended. In the Baltic are two bays, that of Livonia, the most advanced point of which is near Mittau and Riga, and that of Finland, which is a branch of the Baltic, extending between Livonia and Finland to Petersburg, and communicating with Lake Ladoga, and even with Lake Onega, which joins the White Sea by means of the river Onega. The whole body of water which forms the Baltic, the gulfs of Bothnia, of Finland, and of Livonia, ought to be regarded as an immense lake, supported by a great number of rivers, as the Oder, the Vistula, the Niemen, the Droine in Germany and Poland; by other rivers in Livonia and Finland, by others still more considerable which come from Lapland, as the Tornea, the Calis, the Lulea, the Pithea, the Uma; and by several from Sweden. These rivers, which, in general, are large, amount to more than 40, including those which fall into them, and cannot fail to convey a quantity of water sufficient to supply the Baltic. Besides, there are no tides in the Baltic, and its water

water has very little saltnefs : And if the situation of the land, and the number of lakes and marſhes in Finland and Sweden, which are contiguous to the Baltic, be taken into conſideration, we ſhall be inclined to regard it not as a ſea, but as a great lake formed by the waters which it receives from the adjacent countries, and which have forced for themſelves a paſſage near Denmark into the ocean, into which, according to the relation of voyagers, it ſtill continues to run,

From the commencement of the bay which goes by the name of the German Sea, and which terminates beyond Bergen, the ocean follows the coaſts of Norway, Swediſh Lapland, North Lapland, and Muſcovite Lapland, at the eaſtern part of which it forms a large ſtrait, and gives riſe to the mediterranean called the White Sea, which may alſo be conſidered as a great lake ; for it receives twelve or thirteen large rivers, which are more than ſufficient to ſupply it with water ; and its water contains but little ſalt. Beſides, it very nearly, in ſeveral places, communicates with the Baltic ; and it has an evident communication with the gulf of Finland ; for, in aſcending the river Onega, we arrive at a lake of the ſame name, which is joined by two rivers to Lake Ladoga ; and this laſt communicates by a large branch with the gulf of Finland ; and there are, in Swediſh Lapland, ſeveral places from which the waters run almoſt indifferently either into the White Sea or into the gulfs of
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Bothnia and of Finland. This whole country is full of lakes and marshes, and, therefore, it seems probable, that the Baltic and White Seas were the receptacles of its waters; and that, in time, they discharged themselves into the German and Frozen Seas.

On leaving the White Sea, and coasting the island of Candenos, and the north of Russia, the ocean advances a small arm into the land at the mouth of the river Petzora. This arm, which is about 40 leagues in length, by 8 or 10 in breadth, may rather be regarded as a collection of water formed by the river, than as a gulf of the sea; for it also contains very little salt. In this place the land runs out in a promontory terminated by the small islands of Maurice and of Orange; and between this promontory and the neighbouring land to the south of Waigat's strait, there is a bay of about 30 leagues long, which belongs to the ocean, and is not formed by rivers. This is succeeded by Waigat's strait, which lies nearly under the 70th degree of north latitude; it is not above 8 or 10 leagues in length, and it communicates with the sea which washes the north coasts of Siberia. As this strait is blocked up with ice during the greatest part of the year, it is very difficult to penetrate into the sea beyond it. This passage has been tried in vain by many navigators; and those who succeeded have not given us exact charts of the sea, which they call the Pacific Sea.

Sea. By the most recent charts, and by the best globes, it appears, that this sea may be only a mediterranean, having no connection with the great sea of Tartary; for it seems to be shut up and bounded to the south by the country of the Samoides, which is now well known, and which extends from the Straits of Waigat to the mouth of the river Jenisca: To the east, it is bounded by Jelmorland; to the west by Nova Zembla; and, though we know not the extent of this sea to the north and north-east, as the land seems not to be interrupted, it is probable that the Pacific Sea is only a mediterranean; and that it is bounded by land, and has no communication on that side with the ocean. What establishes this fact is, that, in departing from the Straits of Waigat, the whole west and north coasts of Nova Zembla, the length of Cape Desire, have been traversed; that, from this Cape, the coasts of Nova Zembla have been traced to a small bay about the 75th degree, where some Dutchmen passed a dreadful winter in 1596; and that, beyond this gulf, the land of Jelmorland was discovered in 1664, which is separated from Nova Zembla only by a few leagues of land; so that the only land unknown is a small spot near this little bay just now described; and this spot exceeds not, perhaps, 30 leagues in length. If, therefore, the Pacific Sea joins with the eastern ocean, it must be by means of this small bay, which is the only way by which this mediter-

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ranean can have any communication with the eastern ocean. And, even on the supposition that such a communication existed, as this bay lies in the 75th degree of latitude, it would be necessary, to gain this open sea, to keep five degrees farther north. It is apparent, therefore, that, in attempting a north passage to China, it is better to sail beyond Nova Zembla to the 77th or 78th degree, where the sea is more open and clearer of ice, than to persist in passing the frozen straits of Waigat, when it is even uncertain whether the sea beyond them has any communication with the eastern ocean.

The coast has been traced from Nova Zembla and Jelmorland to the mouth of the Chotanga, which is about the 73d degree; beyond which an unknown coast extends about 200 leagues. We only know, from the Russians who travelled by land into these climates, that the country is not interrupted; and, in their charts, the rivers are delineated, and they called the inhabitants *Populi Palati*. This interval of unknown coast extends from the mouth of the Chotanga to that of Kauvoina, in the 66th degree of latitude. The bay of Linchidolin, in which the Russians fish whales, advances farthest into the land at the mouth of the Len, which is a considerable river. This bay is very open, and pertains to the sea of Tartary.

From the mouth of the Len, the northern coast of Tartary runs about 500 leagues east-

ward to a peninsula inhabited by a people called Schelates. It is the most northern point of Tary, and lies under the 72d degree of latitude. In this extent of 500 leagues, the ocean forms neither bays nor arms; only from the peninsula of the Schelates, to the mouth of Korvinea, there is a considerable elbow or projection. This point is the eastern extremity of the north coast of the Old Continent, and Cape North in Lapland is the western extremity. Thus, we have of northern coast from Cape North in Lapland, to the extremity of the country of the Schelates, an extent of 1700 leagues, including the sinuities of bays; and it measures about 1100 leagues in a straight line.

Let us next take a survey of the eastern coasts of the Ancient Continent. We shall begin at the extreme point of the country of the Schelates, and descend towards the equator. The ocean first makes a turn between the country of the Schelates and that of the Tschutschchi, which last projects considerably into the sea. To the south of this country, there is a small open bay, called the bay of Suctoikret. This bay is succeeded by another, which advances, like an arm, about 40 or 50 leagues into the land of Kamtschatka: after which the ocean flows in, by a narrow strait, full of small islands, between the southern point of Kamtschatka and the northern point of the land of Jesso, and forms a large mediterranean, which we shall now describe in detail.

tail. It consists of the sea of Kamtschatka, in which there is a considerable island, called the island of *Amour*. An arm of this sea runs north-east. But, both this arm and the sea of Kamtschatka may, at least in part, be formed by the rivers which flow into it from the lands of Kamtschatka, and those of Tartary. However this matter stands, the sea of Kamtschatka communicates, by a very long strait, with the sea of Corea, which is another part of this mediterranean; and the whole together, extending more than 600 leagues in length, is bounded, on the west and north, by the lands of Corea and Tartary; and, on the east and south, by those of Kamtschatka, Jesso, and Japan, without having any other communication with the ocean than by the strait between Kamtschatka and Jesso; for it is uncertain whether the communication* between Japan and the land of Jesso, though laid down in some charts, has a real existence; and, even supposing it did exist, the sea of Kamtschatka and that of Corea would still be regarded as forming together a great mediterranean, separated on all sides from the ocean, and not as a bay; for it communicates not with the ocean by its southern strait, but with the Chinese Sea, which is rather a mediterranean than a bay.

In the preceding article, it was remarked, that the sea had a constant motion from east to west; and that, consequently, the great Pacific Ocean

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is making continual efforts against the eastern coasts. An accurate examination of the globe will confirm the conclusions we have drawn from this observation; for it appears, that from Kamtschatka to New Britain, discovered by Dampier in 1700, and which lies in the 4th or 5th degree of south latitude, the ocean has encroached on these coasts to the extent of 400 leagues; and, of course, that the eastern bounds of the Old Continent stretch not so far as they did formerly; for, it is remarkable, that New Britain and Kamtschatka, which are the most advanced lands to the east, lie under the same meridian. Besides, all countries extend farthest from north to south. Kamtschatka makes a point of about 160 leagues from north to south, and this point, the eastern coast of which is washed by the Pacific Ocean, and the other by the mediterranean above described, is divided from north to south by a chain of mountains. The lands of Japan and of Jesso form another territory between the ocean and the sea of Corea, extending from north to south more than 400 leagues; and the direction of the chains of mountains in Jesso and Japan must be from north to south; because, in this direction, they extend 400 leagues; but, from west to east, they exceed not 50 or 60. Thus, Kamtschatka, Jesso, and the eastern part of Japan, ought to be considered as contiguous lands, lying in a direction from north to south: and, following
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the same direction, we find, after the point of Cape Ava in Japan, the island of Barnevelt, and three other islands, situated in a line from north to south, and extending about 100 leagues. We next meet with three islands, called Callanos, and, after these, the Ladrone islands, to the number of 14 or 15, all stretched in a line from north to south, the whole occupying a space of 300 leagues in length; and the broadest part of these islands, from east to west, exceeds not 8 leagues. From these facts, I am led to conclude, that Kamtschatka, Jessô, the east part of Japan, the islands of Barnevelt, the Callanos, and the Ladrones, are a continuation of the same chain of mountains, and the remains of an ancient country, which has been gradually corroded and covered with the sea. All these countries appear to be nothing but mountains, of which the islands are the peaks or points, the low-lands being occupied by the ocean. Hence, what is related in the *Lettres Edifiantes* must be true; and, in fact, a number of islands, called the New Philippines, has been discovered in the very situation in which P. Gobien supposed them to lie: and it cannot be doubted, that the most easterly of these New Philippines are a continuation of the chain of mountains which compose the Ladrones; for these eastern islands, to the number of eleven, lie in a line from north to the south, extending in length more than 200 leagues; and, in breadth,

breadth, the largest of them exceeds not eight leagues.

But these conjectures may seem too bold, on account of the great distances between the islands in the neighbourhood of Cape Ava, of Japan, and of the Callanos, between these islands and the Ladrones, and between the Ladrones and the New Philippines, the first interval being about 160 leagues, the second 50 or 60, and the third near 120. But it ought to be considered, that chains of mountains often extend much farther below the waters of the ocean; and that these intervals are nothing when compared to the extent of land, from south to north, in these islands or mountains, which, beginning at the interior part of Kamtschatka, is more than 1100 leagues. But, though this idea concerning the quantity of land gained by the ocean on the eastern parts of the Old Continent, and the continuation of the mountains, should be rejected, still it must be acknowledged, that Kamtschatka, Jesso, Japan, the islands of Rois, Formosa, Vaif, Basha, Babnyane, Lucca, Mindano, Gilolo, &c. and, lastly, New Guinea, which extends to New Britain, and is situated under the same meridian as Kamtschatka, form a stretch of country of more than 2200 leagues, with small interruptions, the greatest of which exceeds not, perhaps, 20 leagues; so that the ocean has scooped out an immense bay from the interior parts of the eastern continent, which begins at Kamtschatka,

schatka, and terminates at New Britain. This bay is interspersed with numerous islands, and has all the appearances of being gained from the land. It is, therefore, probable, that the ocean, by its constant motion from east to west, has gradually gained this great tract of country from the continent, and has formed several mediterraneans, as those of Kamtschatka, of Corea, of China, and perhaps the whole Indian Archipelago; for the land and water are so blended together in this region, that it evidently appears to have been a large country destroyed by inundations, of which only the eminences and mountainous parts are now to be seen, the lower grounds being entirely concealed under the waters of the ocean. This hypothesis is farther confirmed by the shallowness of the sea, and the figures of the innumerable islands, which seem to be nothing but the tops of mountains.

If we take a more particular survey of these seas, we shall find, that the northern part of the Chinese sea forms itself into a great bay, which begins at the island of Fungma, and terminates at the frontiers of the province of Pekin, about 50 leagues from this capital of the Chinese empire. The most advanced and narrowest part of this bay is called the gulf of Changi. It is probable that this gulf, and part of the sea of China, are encroachments of the ocean, and that the islands above described are the most elevated

parts of the ancient country. Farther south are the bays of Tonquin and of Siam, in the neighbourhood of which is the peninsula of Malacca, consisting of a long chain of mountains, that run from north to south; and the Andaman islands, which form another chain of mountains, in the same direction, seem to be only a continuation of those of Sumatra.

The ocean afterwards forms the great bay of Bengal; where it may be remarked, that the land of the peninsula of Indus makes a concave curve, towards the east, nearly resembling the great bay of the eastern continent, which seems to have been produced by the same cause, namely, the motion of the sea from east to west. In this peninsula are the mountains of Gates, which extend from north to south; and the island of Ceylon appears to have been separated from this part of the continent. •

The Maldiva islands are only another chain of mountains stretching from north to south. Then follows the Arabian gulf, which sends off four branches or arms; the two largest are on the west coasts, and the two smallest on the east. The first arm on the east coast is the bay of Cambaia, which extends not above 50 or 60 leagues; but it receives two considerable rivers, the Tapta and the Baroche or Mehi. The second arm or bay on the same coast is remarkable for the rapidity and height of its tides, which alternately advance and retreat more than

50 leagues. Into this bay fall several rivers, as the Indus, the Padar, &c. which have brought down sand and mud in such quantities as to elevate the bottom of the bay, and reduce it nearly to a perfect level. It is owing to this circumstance that the tides extend to so great a distance. The first arm on the west coast is the Persian gulf, which advances into the land above 250 leagues; and the second is the Red Sea, which, reckoning from the island of Socotora, extends above 680 leagues. From the straits of Ormuz and of Babelmandel, these two arms should be considered as mediterranean seas: they are both, indeed, subjected to a flux and reflux; but this circumstance is occasioned by their vicinity to the equator, where the tides rise higher than in other climates. Besides, they are both very long and very narrow. The motion of the tides is more rapid in the Red Sea than in the Persian gulf; because the former is nearly three times as long, and equally narrow, as the latter; neither does it receive any river capable of resisting the tide: but the Persian gulf receives three large rivers at its most advanced extremity. It is apparent, that the Red Sea has been formed by an irruption of the ocean; for the situation and similarity in the direction of the coasts on each side of the straits of Babelmandel show, that this passage has been cut by the waters.

At the extremity of the Red Sea lies that famous strip of land called the Isthmus of Suez, which

which is a barrier to the junction of the Red Sea with the Mediterranean. In the preceding article, I gave the reasons which render it probable that the Red Sea is higher than the Mediterranean, and that, if the Isthmus were cut, an inundation and increase of the latter would be the consequence. It may here be added, that, though the superior elevation of the Red Sea should not be allowed, yet it is incontestible, that there are no tides in the Mediterranean near the mouths of the Nile. It is equally certain, that the tides in the Red Sea rise several feet; and this circumstance alone, on the supposition of the removal of the Isthmus, would occasion a great influx of water from the Red Sea into the Mediterranean. Besides, Varenius, in his geography*, remarks, ‘Oceanus Germanicus, qui est Atlantici pars, inter Frisiam et Hollandiam se effundens, efficit sinum, qui, etsi parvus sit respectu celebrium sinuum maris, tamen et ipse dicitur mare, alluitque Hollandiæemporium celeberrimum, Amstelodamum. Non procul inde abest lacus Harlemonsis, qui etiam mare Harlemonse dicitur. Hujus altitudo non est minor altitudine sinus illius Belgici, quem diximus, et mittit ramum ad urbem Leidam, ubi in varias fossas divaricatur. Quoniam itaque nec lacus hic, neque sinus ille Hollandici maris inundant adjacentes agros, (de naturali constitutione loquor, non ubi tempestatibus

* Page 100.

‘ urgentur, propter quas aggeres facti sunt ;) pa-
 ‘ tet inde, quod non sint altiores quam agri Hol-
 ‘ landiæ. At vero Oceanum Germanicum esse
 ‘ altio-rem quam terras hæc, experti sunt Lei-
 ‘ denses, cum suscepissent fossam seu alveum ex
 ‘ urbe sua ad Oceani Germanici littora, prope
 ‘ Cattorum vicum perducere, (distantia est duo-
 ‘ rum milliarium) ut, recepto per alveum hunc
 ‘ mari, possent navigationem instituere in Ocea-
 ‘ num Germanicum, et hinc in varias terræ re-
 ‘ giones. Verumenimvero, cum magnam jam
 ‘ alvei portam perfecissent, desistere coacti sunt,
 ‘ quoniam tum demum per observationem cog-
 ‘ nitum est, Oceani Germanici aquam esse altio-
 ‘ rem quam agrum inter Leidam et littus Ocea-
 ‘ ni istius: Unde locus ille, ubi fodere desie-
 ‘ runt, dicitur *Het malle Gat*. Oceanus itaque
 ‘ Germanicus est aliquantum altior quam finis
 ‘ ille Hollandicus,’ &c. . As the German ocean,
 therefore, is higher than the sea of Holland, no-
 thing prevents us from believing that the Red Sea
 may be higher than the Mediterranean. Hero-
 dotus and Diodorus Siculus mention a canal of
 communication between the Nile, the Mediter-
 ranean, and the Red Sea: And M. de l’Isle, in
 1704, published a map, where he has laid down
 the termination of a canal in the east branch of
 the Nile, which he imagined to be a part of
 the canal which formerly joined that river to
 the Red Sea*. We meet with the same opinion.

* See Mem. de l’Acad. des Sciences, année 1704.

in a book entitled *Gonnoissance de l'Ancien Monde*; where the author, copying Diodorus Siculus, informs us, that this canal was begun by Neco King of Egypt; that Darius King of Persia continued the work; that it was finished by Ptolèmy II. who conducted it to the city of Arsinoë; and that it could be shut and opened at pleasure. I pretend not to deny these facts; but, I confess, they appear to be doubtful. I suspect, that the violence and height of the tides in the Red Sea, would necessarily communicate their influence to the waters of the canal: At least, it would require great precaution to prevent inundations, and to keep the canal in proper repair. Though we are told by historians that this canal was begun and finished, they are silent as to its duration; and the remains of it, which are pretended still to exist, are perhaps the only parts of it that ever were executed. This branch of the ocean has been denominated the *Red Sea*, because, wherever there are madrepores or corals at the bottom, the water of it has the appearance of being red. The following description of it is given in the *Histoire Generale des Voyages**: ‘ Before leaving the Red Sea, D. Jean inquired into the causes which induced the ancients to give it this appellation: He recollected, that Pliny had delivered several opinions concerning the origin of this name. Some derived it from a King of that

* Tom. i. p. 198.

country called *Erythros*, which, in the Greek language, signifies *Red* : Others imagined that the red colour was occasioned by the reflection of the sun from the surface of the water ; and others affirmed that the water itself was red. The Portuguese, who had made several voyages in that sea, alledged, that the whole coast of Arabia was remarkably red ; and that the dust and sand carried into the sea by the winds tinged the water with the same colour.

Dom Jean, who examined the nature of the water and of the coasts, through their whole extent, with the most scrupulous attention, assures us, that the waters of this sea have no peculiarity in their colour ; and that the dust and sand, not being red themselves, could not possibly communicate this colour to the water. The land on each side, he observes, is generally brown ; in some places, it is black, and, in others, white : At Suaquem, the coasts of which the Portuguese never visited, there are three mountains striped with red ; but they consist of hard rocks, and the neighbouring ground is of the usual colour.

The truth is, that this sea is all of the same uniform colour, of which any man may satisfy himself by drawing water from different parts. But, it must be acknowledged, that, in some places, it appears, by accident, to be red, and, in others, green and white. This phenomenon .

‘ nomenon admits of the following explication.
 ‘ From Suaquem to Koffir, which is an extent of
 ‘ 136 leagues, the sea is filled with banks and
 ‘ rocks of coral; they are so called from their
 ‘ resembling coral in form and colour so exact-
 ‘ ly, that it is difficult to perceive the distinction:
 ‘ There are two kinds of them, the one is white,
 ‘ and the other extremely red. In many places,
 ‘ they are covered with a kind of gum, or viscid
 ‘ substance of a green colour, and sometimes of
 ‘ a deep orange. Now, the water of this sea is
 ‘ so transparent, that the bottom is visible at the
 ‘ depth of twenty fathoms, especially from
 ‘ Suaquem to the extremity of the gulf; and
 ‘ hence the water assumes, in appearance, the co-
 ‘ lour of the bodies which it covers. When,
 ‘ for example, the rocks are overlaid with a
 ‘ green gum, the water above them appears to
 ‘ be green; when the bottom is sand alone, the
 ‘ superincumbent water seems to be white; and,
 ‘ when the rocks are covered with coral, the
 ‘ water above them appears to be reddish. But,
 ‘ as the rocks of this colour are more frequent
 ‘ than the green or white, Dom Jean concludes,
 ‘ that the Arabic Gulf has, from this circum-
 ‘ stance, obtained the name of the Red Sea.
 ‘ He was the more satisfied with this discovery,
 ‘ because the method he employed in the inve-
 ‘ stigation of it left no room for hesitation or
 ‘ doubt. In such places as were not deep
 ‘ enough to allow his vessel to sail, he fastened

‘ pinks opposite to the rocks ; and the sailors
 ‘ were enabled to execute his orders, at more
 ‘ than half a league from the rocks, without be-
 ‘ ing immerfed above the middle of their bodies.
 ‘ In thofe places where the water appeared red,
 ‘ the greateft part of the ftones and pebbles they
 ‘ brought up were of the fame colour ; where
 ‘ the water appeared green, the ftones were
 ‘ green alfo ; and where the water appeared
 ‘ white, the bottom was a pure white fand.’

From the entrance to the Red Sea, at Cape Gardafu, to the Cape of Good Hope, the direction of the coaft is pretty equal, and the fea forms no bay of any note. There is, indeed, a fmall fcoop on the coaft of Melinda, which, if the Ifland of Madagafcar were united to the continent, might be confidered as a part of a large bay. This ifland, it is true, though feparated by the ftraits of Mozambique, appears to have formerly belonged to the continent ; for, in this ftrait, there are high fands of great extent, efpecially on the Madagafcar coaft, which render the open part of it very narrow.

From the Cape of Good Hope to Cape Negro, on the weft coaft of Africa, the land lies in the fame direction ; and the whole of it feems to be a chain of mountains : It is, at leaft, a very elevated country, and, though more than 100 leagues in length, it is furnifhed with no rivers of any confideration, except one or two, which are known no farther than their mouths.

mouths. But the coast, above Cape Negro, makes a large curve ; and the land, along this curve, appears to be lower than that of the rest of Africa : It is watered by several great rivers, the largest of which are the Coanza and the Zaire. From Cape Negro to Cape Gonfálvez, are the mouths of 24 considerable rivers ; and the space between these two capes, reckoning along the shore, is about 420 leagues. We would be tempted to think, that the ocean has encroached on these low lands of Africa, not by its natural motion from east to west, which could have no influence in producing this effect, but by the facility with which it might have undermined and surmounted them. From Cape Gonfálvez to Cape Trois-pointes, the ocean forms an open bay, which presents nothing remarkable, except a very advanced point nearly in the middle of it, called *Cape Formosa* : It likewise contains, in the southern part of it, the islands of Fernandpo, St. Thomas, and Prince's Island. These islands appear to be a continuation of a chain of mountains situated between Rie del Rey, and the river Jamoer. From Cape Trois-pointes to Cape Palmas, the ocean runs a little in upon the land ; and from Cape Palmas to Cape Tagrin, there is nothing worthy of remark. But, beyond Cape Tagrin, there is a small bay in the country of Sierra-Leona ; and a little farther, there is another, in which are situated the islands of Bisagas. We after-

wards meet with Cape Verd, which projects far into the sea, and of which the islands of the same name appear to be a continuation; or, rather, they seem to be a continuation of Cape Blanc, which is a more elevated country, and stretches still farther into the ocean. We next come to a mountainous and dry coast, which commences at Cape Blanc, and terminates at Cape Bajador: The Canary islands seem to be a continuation of these mountains. Lastly, between Africa and Portugal, is a large open bay, in the middle of which are the celebrated Straits of Gibraltar. The ocean pours its waters, with great rapidity, through this strait into the Mediterranean. This sea runs into the interior parts of the land near 900 leagues, and gives rise to many objects worthy of remark. 1st, It has no perceptible tides, except in the Gulf of Venice; and a small flux and reflux have been alledged to take place at Marseilles and on the coast of Tripoli. 2^d, It contains many large islands, as Sicily, Sardinia, Corfica, Cyprus, Majorca, &c. and Italy, which is one of the most extensive peninsula's in the world: It is likewise adorned with a rich Archipelago, or rather, it is from the Mediterranean Archipelago that all other collections of islands have acquired that appellation. But this Archipelago appears to belong more properly to the Black Sea than to the Mediterranean; and it is probable, that the country of Greece was partly covered with the Black Sea, which

which runs into the sea of Marmora, and from that into the Mediterranean.

It has been alledged, that a double current runs through the Straits of Gibraltar; one superior, which carries the waters from the ocean into the Mediterranean, and another inferior, which carries the waters from the Mediterranean back to the ocean. But this notion is false, and contrary to the known laws of hydrostatics. Opposite currents have been ascribed to several other straits, as the Bosphorus, the straits of Sunda, &c.; and Marfilli has related many experiments tending to prove the existence of a superior and inferior current in the Bosphorus. These experiments, however, must have been fallacious; for such a phenomenon is repugnant to the nature and motion of fluids. Besides, Greaves, in his *Pyramidographie*, has demonstrated by accurate experiments, that there are no opposite currents in the Bosphorus. Marfilli and others may have been deceived by the regorging of the water near the shores, which takes place in the Bosphorus, in the straits of Gibraltar, and in all rapid rivers, and which often produces a motion opposite to that of the principal current.

Let us now briefly run over the coasts of the New Continent. We shall begin with Cape Hold-with-hope, which is situated in the 73d degree of North Latitude. This is the most northerly point of land in New Greenland, and
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is distant from Cape North in Lapland about 160 or 180 leagues. From this cape the coast of Greenland might be traced to the polar circle, where the ocean forms a large strait between Iceland and Greenland. Some maintain, that this country in the neighbourhood of Iceland is not the Ancient Greenland, formerly possessed by the Danes as a dependent province. Its inhabitants were civilized Christians, who had bishops, churches, and a number of towns proportioned to their trade. The Danes had a communication with them as easy, and as frequent, as the Spaniards with the Canary islands: There still exists, it is said, laws and regulations with regard to the government of this province, and these not of a very ancient date. However, without forming any conjectures how this country came to be absolutely lost, we find not in New Greenland the least vestige of what is here related. They are mere savages: They have no buildings: There is not a word in their language that has the smallest affinity to the Danish tongue; and there is not a single circumstance from which we can infer it to be the same country. It is even almost a desert, and is covered with snow and ice the greatest part of the year. But, as these lands are of vast extent, and, as the coasts have been little frequented by modern navigators, they may have missed the place occupied by the descendants of these polished people; or the increase of the ice in

in this sea may now, perhaps, prevent all access to them. If, however, maps can be trusted, the whole coast of this country is known: It forms a large peninsula, at the extremity of which are the two straits of Frobisher and of Friesland, where the cold is excessive, although they are not farther north than the Orkneys, that is, about 60 degrees.

Between the west coast of Greenland, and that of Labrador, the ocean forms a gulf, and then a large mediterranean, which is the coldest of all seas, and its coasts are little known. In pursuing this gulf, we meet with Davis's strait, which leads to the Christian sea, which last terminates in Baffin's bay, through which there appears to be an outlet into Hudson's bay. The strait of Cumberland, which, like that of Davis, may lead into the Christian sea, is more narrow, and more subject to be frozen. Hudson's strait, though much farther south, is also frozen for some part of the year: And it is remarkable, that the tides are very high in those seas and straits, although no tides take place in the inland seas of Europe, as the Baltic and Mediterranean. This difference seems to be occasioned by the motion of the sea from east to west, which produces high tides in straits opposite to the current of the waters, or whose mouths open to the east. But, in those of Europe, which open to the west, there are no tides. The ocean, by its general movement, rushes into the former, but flies

flies from the latter ; and this is the reason why the tides are so violent in the seas of China, Corea, and Kamtschatka.

In sailing down Hudson's bay towards Labrador, there is a narrow opening, 30 leagues of which Davis traversed in 1586, and traded with the inhabitants. But no attempts have hitherto been made to discover the whole of this arm of the sea. We know nothing of the neighbouring country, but the land of the Esquimaux. Fort Ponchartrín is the only settlement, and the most northerly part of this country ; and it is separated from the island of Newfoundland by the small strait of Belleisle, which is little frequented. As the eastern coast of Newfoundland has the same direction with that of Labrador, this island appears to have been formerly a part of the continent, in the same manner as Isle-royal seems to have been detached from Acadia. The bottoms of the great bank, and of the lesser banks on which the cod-fishery is carried on, are not deep ; but, as they shelve a great way under water, they produce violent currents. Between Cape Breton and Newfoundland, there is a pretty large strait, which is the mouth of a small mediterranean, called the *Gulf of St. Laurence*. It sends off a branch, which extends a considerable way into the country, and appears to be only the mouth of the river of that name. In this arm of the sea the tides are very perceptible ; and, even at
Quebec,

Quebec, which is farther up the country, the waters rise several feet. Leaving the gulf of St. Laurence, and following the coast of Acadia, we meet with a small gulf called *Boston-Bay*, which is of a square figure, and advances a little way only into the land. But, before we pursue this coast any farther, it is worthy of remark, that, from Newfoundland to Guiana, the ocean forms an immense bay, that runs in upon the land as far as Florida, which is more than 500 leagues. This bay is similar to that of the Old Continent above described, where the ocean, after forming a large gulf between Kamtschatka and New Britain, gives rise to a great mediterranean, which comprehends the sea of Kamtschatka, of Corea, of China, &c. In the same manner, in the New Continent, the ocean, after forming a large gulf between Newfoundland and Guiana, gives rise to a great mediterranean, extending from the Antilles to Mexico; which confirms what we have advanced concerning the motion of the sea from east to west: For it appears that the ocean has gained as much territory on the east coast of America as on the east coast of Asia. Besides, these great gulfs in each continent lie under the same degrees of latitude, and are nearly of equal extent. Such singular relations, it would appear, must have been produced by the same cause.

If we examine the position of the Antilles, beginning with the island of Trinidad, which is
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the southmost, it is impossible to doubt but that Trinidad, Tobago, the Granades, St. Vincent, Martinico, Marygalante, Antego, Barbadoes, and all the adjacent isles, once formed a chain of mountains, which extended from south to north, like Newfoundland and the country of the Esquimaux. Farther, the direction of the Antilles from east to west, if we begin with Barbadoes, and pass on to St. Bartholomy, Porto-Rico, St. Domingo, and Cuba, is nearly the same with the coasts of Cape Breton, Acadia, and New England. All these islands lie so contiguous, that they may be regarded as a continued belt of land, and as the most elevated parts of a country now occupied by the sea. Most of them are nothing but the tops of mountains; and the sea between them and the continent is a true mediterranean, in which the tides are not much more perceptible than in our Mediterranean, although the straits between the islands are directly opposed to the motion of the sea from east to west, which should contribute to raise the tides in the gulf of Mexico. But, as this gulf is very broad, the waters elevated by the tide when expanded over a large surface, hardly produce any sensible change upon the coast of Louisiana and several other places.

Both the Old and New Continents, therefore, appear to have been encroached upon by the ocean in the same latitudes: Both are furnished with a great mediterranean, and a vast number
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of islands, which likewise lie nearly in the same latitudes. The only difference is, that the Old Continent, being much larger than the New, has a mediterranean on its west coast, to which the New Continent has nothing analogous. But both seem to have undergone similar revolutions. These revolutions are greatest near their middle parts, or between the tropics, where the motion of the sea is most violent.

The coasts of Guiana, from the mouth of the river Oronoko to that of the Amazons, exhibit nothing remarkable. But the Amazons, which is the largest river in the universe, forms a considerable sheet of water near Coropa, before it discharges itself into the sea by the ~~two~~ mouths which surround the island of Caviana. From the mouth of the Amazons to Cape St. Roche, the river runs almost straight east; from Cape St. Roche to Cape St. Augustine it runs south, and from Cape St. Augustine to the bay of All Saints, it runs westward in such a manner that this part of Brasil projects considerably into the ocean, which is directly opposite to a similar projection of the African coast. The bay of All Saints is a small arm of the sea, which advances about 50 leagues into the land, and is much frequented by navigators. From this bay to Cape St. Thomas, the coast runs straight south, and from thence, in a south-west direction, to the mouth of the Plata, where an arm of the sea projects about 100 leagues into the land.

From this river, to the southern extremity of America, the ocean forms a large bay, which is terminated by Falkland Island, Cape Assumption, and other lands bordering on Terra del Fuego. At the bottom of this bay is the strait of Magellan, the longest in the universe, and where the tides rise very high. Beyond this is the strait of La Maire, which is much shorter; and, *lastly*, Cape Horn, which is the south point of America.

On the subject of points or head-lands, it is remarkable, that they all regard the south, and that most of them are cut by straits which run from east to west. The point of South America regards the Arctic Pole, and it is cut by the strait of Magellan: That of Greenland, which likewise has a southern aspect, is cut from east to west by the strait of Frobisher: That of Africa regards also the south, and, beyond the Cape of Good Hope, are banks and shoals which appear to have been separated from it: That of the peninsula of India is cut by the strait between it and the island of Ceylon; and, like all others, projects southward. These are facts; but we are unable to give any explication of them.

From Terra del Fuego, all along the west coast of South America, the ocean makes considerable advances into the land; and this coast seems to follow exactly the direction of the high mountains which traverse this part of the continent
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from south to north, from the Equator to the Arctic Pole. Near the Line, the ocean forms as large bay, extending from Cape St. Francois to Panama, that famous isthmus, which, like that of Suez, prevents the junction of the two seas. If these two necks of land were removed, both the Old and the New Continent would be divided into two distinct portions. From Panama to California, there occurs nothing worthy of remark. Between the peninsula of California and New Mexico, is a long arm of the ocean, called the *Vermilion Sea*, which is more than 200 leagues long. In fine, the west coast of California has been traced to the 43^d degree of latitude. It was in this latitude that Drake, who first discovered the land to the north of California, and which he called *New Albion*, was obliged, by the rigour of the cold, to change his course, and to anchor in a small bay which bears his name; so that the countries beyond the 43^d or 44th degree, in this part of the globe, are as little known as those of North America beyond the 48th degree, which is inhabited by the Moozemleki, and the 51st, which is inhabited by the Assiniboils. The territory of the former savages extends much farther west than that of the latter. All beyond, for 1000 leagues in length, and as much in breadth, is totally unknown, unless the Russians, as they pretend, have made some discoveries by departing from

Kamtschatka, and visiting the eastern coasts of North America.

The ocean, then, surrounds the whole globe, without interruption, and we may sail round it by taking our departure from the south point of America. But we are still uncertain whether the ocean surrounds, in the same manner, the north part of the globe; and all the navigators, who have attempted to go from Europe to China by the north-east or north-west, have equally failed in their enterprises.

Lakes differ from mediterraneans; the former derive no water from the ocean; on the contrary, when they communicate with seas, they are constantly discharging water into them. Thus the Black Sea, which some geographers have regarded as a branch of the Mediterranean, and, of course, as an appendage of the ocean, is only a lake; because, in place of receiving any supplies from the Mediterranean, its waters run with rapidity through the Bosphorus into the lake called the Sea of Marmora, and from thence through the straits of the Dardanelles into the Grecian Sea. The Black Sea is about 250 leagues long, and 100 broad: It receives a number of large rivers, as the Danube, the Nieper, the Don, the Boh, the Donjec, &c. The Don, which unites with the Donjec, before it arrives at the Black Sea, forms a lake called the *Palus Meotis*; which is more than 100 leagues in length, and from 20 to 25 in breadth. The Sea
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of Marmora, which is below the Black Sea, is a lake smaller than the Palus Meotis, being not above 50 leagues long, and 8 or 9 broad.

It is related by some of the ancients, and particularly by Diodorus Siculus, that the Euxine, or Black Sea, was originally a great river or lake, and had no communication with the Greek Sea; but that its waters were, in the course of time, so greatly augmented by the rivers which fall into it, that they forced a passage, first by the islands of Cyanea, and then by the Hellespont. This opinion has great probability on its side; and, I think, it is no difficult matter to explain how the operation was effected: For, supposing the bottom of the Black Sea to have been formerly much lower than it is now, the mud and sand carried down by the rivers would gradually raise it, till the surface of the water was elevated above that of the land, and then the water would necessarily find a passage for itself: and, as the rivers continue still to transport sand and earth, and as, at the same time, the quantity of water in the rivers diminishes in proportion as the mountains from which they spring are lowered, it may happen, in the course of ages, that the Bosphorus will again be filled up. But, as effects of this nature depend on many causes, we must content ourselves with simple conjectures. Mr. Tournefort, on the authority of the ancients, says, that the Black Sea, which receives the waters of a great part of Eu-

rope and Asia, after being considerably augmented, opened to itself a passage by the Bosphorus, and either formed the Mediterranean, or increased its waters to such a degree, that they forced a passage to the ocean through the straits of Gibraltar; and that the island of Atalantis, mentioned by Plato, was, on this occasion, totally overflowed. This notion cannot be supported; for the ocean runs into the Mediterranean, and not the Mediterranean into the ocean. Besides, M. Tournefort has not combined two essential facts, though he has mentioned both of them. The first is, that the Black Sea receives 9 or 10 rivers, each of which furnishes more water than is discharged by the Bosphorus; and the second, that the Mediterranean does not receive more water from rivers than the Black Sea, though it be seven or eight times larger; and what it receives from the Bosphorus is not the tenth part of what falls into the Black Sea. How, therefore, could this tenth part of the water that falls into a small sea, produce not only a larger sea, but augment its waters to such a degree as would enable it to break down the isthmus of Gibraltar, and overwhelm an island of greater extent than the whole of Europe? It is easy to perceive that M. Tournefort has not sufficiently considered this matter. The Mediterranean derives from the ocean at least ten times the quantity of water it receives from the Black Sea; for the narrowest part of the Bosphorus

Bosphorus exceeds not 800 paces, while that of the straits of Gibraltar is more than 5000; and supposing the velocities of both to be equal, still the water in the straits of Gibraltar is by much the deepest.

M. Tournefort, who ridicules Polybius for predicting that the Bosphorus will in time be filled up, has not attended sufficiently to circumstances, otherwise he would not have pronounced the impossibility of such an event. Must not the Black Sea, which constantly receives the sand and mud of eight or ten large rivers, gradually fill up? Must not the winds and the natural current of the waters continually transport part of these matters into the Bosphorus? It is, therefore, extremely probable, that, in the course of ages, the Bosphorus will be choaked up, when the quantity of water discharged by the rivers into the Black Sea shall be greatly diminished. Now, the rivers are diminishing daily, because the mountains, which collect the dews, and give rise to the rivers, are continually decreasing.

• The Black Sea receives more water from rivers than the Mediterranean; and M. Tournefort observes, on this subject, ‘ That the greatest rivers in Europe fall into this sea by means of the Danube, into which are discharged the rivers of Suabia, Franconia, Bavaria, Austria, Hungary, Moravia, Corinthia, Croathia, Bothnia, Servia, Transylvania, and Wallachia: the rivers of Black Russia and of Podolia fall like-

' wise into the same sea by means of the Niester;
 ' those of the southern and eastern parts of Po-
 ' land, of the northern part of Muscovy, and of
 ' the country of the Cossacks, fall into it, either
 ' by the Nieper or Boristhenes; the Tanais and
 ' the Copa empty themselves into the Black Sea
 ' by the Cimmerian Bosphorus; the rivers of
 ' Mingrelia, the principal of which is the Phasis,
 ' also discharge their contents into this sea, and
 ' likewise the Casalmac, the Sangaris, and other
 ' rivers of Asia Minor which take a northern
 ' course: but the discharge through the Thra-
 ' cian Bosphorus, which is the only outlet from
 ' the Black Sea, is not comparable to that of
 ' any one of these great rivers *.'

All these facts demonstrate the great quantity
 of water carried off by evaporation; and it is
 owing to this circumstance that the ocean con-
 stantly runs into the Mediterranean by the straits
 of Gibraltar. It is difficult to ascertain the quan-
 tity of water received by any sea; it requires an
 exact knowledge of the breadth, depth, and ve-
 locity of all the rivers that fall into it, of their
 augmentation and diminution in different sea-
 sons of the year, and of the quantity which the
 sea loses by evaporation. This last is the most
 difficult to determine; for supposing evapora-
 tion to be proportioned to the surfaces, it will
 be greater in a warm than in a cold climate.

tides, water mixed with salt and bitumen eva-

* See voyage du Levant de Tournefort, vol. ii. p. 123.
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porates more slowly than fresh water; a sea subject to great agitation evaporates more quickly than a calm sea; and a difference in the depth has also some effect. In fine, so many particulars are included in the theory of evaporation, that it is not possible to make an exact estimation of its quantity.

The water of the Black Sea is less clear and less salt than that of the ocean. There are no islands in it; and its tempests are more violent and more dangerous than those of the ocean; because its waters, being extended in a basin which has but an inconsiderable outlet, move, when agitated in a kind of whirlpools, which beat upon all sides of a vessel with an insupportable violence*.

After the Black Sea, the greatest lake in the world is the Caspian Sea, which extends from south to north about 300 leagues, and its mean breadth exceeds not 50. This lake receives the Wolga, besides several other considerable rivers, as the Kur, the Faie, and the Gempo. But, what is singular, it receives not one river from the east coast; the country on that side is a sandy desert, which remained, till lately, altogether unknown. The Czar Peter I. sent engineers to make a chart of the Caspian Sea. It had been represented as round by former geographers; but it is very long and very narrow. Its eastern coast, and the neighbouring country, were

* See voyages de Chardin, p. 142.

entirely unknown; even Lake Aral, which is about 100 leagues east of the Caspian, was either not known to exist, or was considered as a part of this sea. Thus, before the discoveries of the Czar, there was in this region an unknown country of 300 leagues in length, and 100 or 150 in breadth. Lake Aral is nearly oblong, and about 90 or 100 leagues long, and 50 or 60 broad. It receives the Sideroias and the Oxus, two large rivers; but, like the Caspian, it has no outlet for discharging its waters; and, as the Caspian receives no rivers from the east, Lake Aral, on the contrary, receives none from the west. Hence, it is presumable, that these two formerly constituted but one lake; and the rivers being gradually choaked up, the country between them would necessarily be covered with sand. There are some small islands in the Caspian; and its waters are much fresher than those of the ocean. Storms, in this sea, are exceedingly dangerous; and it affords not navigation to large vessels, on account of shoals, sand-banks, and rocks concealed under the surface. ‘The largest vessels employed on the Caspian,’ says Pietro della Valle*, ‘along the coasts of the province of Mazanda in Persia, where stands the town of Ferhabad, although they be called *ships*, are no better than our tarantans: their sides are high; they draw little water, and are flat-bottomed. They are built of this

* Tom. iii. p. 235.

' construction, not only because this sea is shal-
 ' low near the coasts, but because it is full of
 ' shoals and sand-banks; so that no other vessels
 ' could be used with safety. I was surprised
 ' to see no fishing carried on at Ferhabad, ex-
 ' cept salmons at the mouth of the river, a
 ' bad kind of sturgeon, and other fresh water
 ' fishes of no value. I attributed this to their
 ' ignorance of navigation and of the art of fish-
 ' ing, till I was informed by the Cham of Ester-
 ' abad, that this sea, at the distance of 20 or 30
 ' miles from the shore, is so shallow, that nets
 ' could not be used with advantage; and that
 ' the same reason accounted for the construction
 ' of their vessels, which carry no cannon, because
 ' the Caspian is not infested with pirates.'

Struys, Avril, and others, affirm, that, in the
 neighbourhood of Kilan, there are two gulfs,
 which swallow up the waters of the Caspian, and
 carry them, by subterraneous passages, into the
 Persian Gulf. De Fer, and other geographers,
 have laid down these gulfs in their maps,
 though we are assured by the Czar's envoys,
 that they have no existence*. The fact, with
 regard to the willow leaves found on the Persian
 Gulf, and which are alledged by the same au-
 thors to be transported from the Caspian Sea,
 because no willows grow near the Persian Gulf,
 appears to be equally improbable, as the subter-
 raneous passages, which Gemelli Careri, as well

* See Mem. de l'Acad. des Sciences, année 1721.

as the Russians, maintain to be altogether imaginary. Besides, the Caspian is about a third less than the Black Sea, which last also receives more water by rivers; evaporation, therefore, is alone sufficient to carry off all its adventitious waters, without the assistance of imaginary gulfs, or subterraneous passages.

There are lakes, or seas, which neither receive nor discharge rivers; there are others which both receive and discharge, and others which only receive. The Caspian, Lake Aral, and the Dead Sea, are of the last kind: In Asia Minor, there is a small lake of the same species: There is another still larger in Persia, upon which the city of Marago is situated: It is of an oval figure, and about 10 or 12 leagues long, and 6 or 7 broad: It receives the Tauris, which is not a very considerable river. If to these we add a small lake of the same nature in Greece, 12 or 15 leagues from Lepanto, we have an enumeration of all the known lakes in Asia which belong to this species. In Europe, there is not a single one of any consideration. There are several small lakes of this kind in Africa, as those which receive the rivers Ghir, Zez, Touguedot, and Tafilet. These four lakes lie at no great distance from one another, and are situated on the frontiers of Barbary, near the desert of Zaara. There is another in the province of Kovar, which receives the river that runs through the country of Berdoa. In
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North America, which abounds with lakes, there are none of this kind, except two small collections of water formed by brooks, the one near Guatimapo, and the other some leagues from Realnuevo, both in Mexico. But in Peru there are two contiguous lakes, one of which, Lake Taticaca, is very large, and receives a river which rises near Cusco; but it gives rise to no river. There is a small lake in Tucuman, which receives the river Salta; another, in the same country, of greater extent, receives the Santiago; and three or four between Tucuman and Chili.

Those lakes, which neither receive nor give rise to any river, are more numerous than the kind just mentioned. They are a species of swamps, which collect the rain water; or, they may originate from subterraneous waters that issue in the form of springs in low grounds, from which there is no fall to carry them off. Those rivers that overflow may also leave stagnating waters upon the land, which remain a considerable time, and are occasionally recruited by subsequent inundations. Salt lakes may sometimes be produced by inundations from the sea, as that at Harlem, and several others, in Holland, to which no other origin can be ascribed. The sea, likewise, by abandoning certain lands, may have left lakes in the low grounds of particular countries, and which continue to be maintained by the rains. Of this kind, there
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are small lakes in Europe, as in Ireland, in Jutland, in Italy, in the country of the Grisons, in Poland, in Muscovy, in Finland, and in Greece: But all these are of little consideration. In Asia, near the Euphrates, in the desert of Irac, there is one above 15 leagues long; another in Persia, nearly of the same extent, upon which are situated the towns of Kelat, Tetuan, Vastan, and Van; a small one in Chorazan, near Ferrior; another in Independent Tartary, called *Lake Levi*; two in Muscovite Tartary; one in Cochinchina; and, in fine, a pretty large one not far from Nankin. This last, however, communicates with the neighbouring sea by a canal of considerable extent. In Africa, there is a small lake of this species in the kingdom of Morocco; another near Alexandria, which appears to have been left by the sea; another, 8 or 10 leagues long, formed by the rain-water, in the desert of Azarad, about the 30th degree of latitude; another, still larger, upon which is situated the town of Gaoga, under the 27th degree; another, but much smaller, near the town of Kanum, under the 30th degree; one near the mouth of the river Gambia; several others in Congo, about the 2d or 3d degree of south latitude; two others in the country of the Caffres; one of them, called *Lake Rufumbo*, is not very extensive; and the other, which lies in the province of Arbuta, is perhaps the largest of this kind, being about 25 leagues long, and 7 or 8 broad;

§ broad: There is likewise one of these lakes near the east coast of Madagascar, about the 29th degree of south latitude.

In America, there is one of these lakes situated in the middle of the peninsula of Florida, which has an island called *Serrope* in its centre. The lake near the town of Mexico, which is round, and about 10 leagues in diameter, belongs likewise to this species. There is another still more extensive in New Spain, about 25 leagues from the eastern coast of the bay of Campeachy; and another, of smaller dimensions, in the same country, near the coast of the South Sea. Some travellers have affirmed, that, in the interior parts of Guiana, there is a very large lake of this species, which they call *Golden Lake*, or *Lake Parima*; and they have given marvellous accounts of the riches of the neighbouring country, and of the great quantities of gold dust found in this lake, which they alledge to be more than 400 leagues in length, and above 125 in breadth: No river, it is said, either enters into or issues from it. Though this lake be laid down in several maps, its existence is still problematical.

But the most common and the most extensive lakes are those which both receive and give rise to rivers: As they are exceedingly numerous, I shall only mention the largest, or the most remarkable of them. Beginning with Europe, we have, in Switzerland, the Lake of Geneva, that

that of Constance, &c. In Hungary, Lake Balaton, and another, of equal extent in Livonia, which separates this province from Russia; Lake Lapwert in Finland, which is very long, and divides into several branches, and Lake Oula, which is of a circular figure: In Muscovy, Lake Ladoga, which is more than 25 leagues long, and above 12 broad; Lake Onega, which is equally long, but not so broad; Lake Ilmen; Lake Belozero, which is one of the sources of the Wolga; Lake Iwan-Osero, which is one of the sources of the Don; and two other lakes, from which the river Vitzogda derives its origin: In Lapland, the lake from which issues the river Kimi; another, much larger, and situated near the coast of Wardhus; and several others of less note, which give rise to the rivers Lula, Pitha, and Uma: In Norway, two lakes nearly of the same dimensions with those of Lapland: In Sweden, Lake Vener, which is as large as Lake Meller, upon which Stockholm is situated; and two less considerable, one near Elvedal, and the other near Lincopin.

In Siberia and in Muscovite and Independent Tartary, there are a great number of these lakes, of which the principal are, the great lake Baraba, which is more than 100 leagues long, and the waters of which fall into the Irtis; the great lake Estraguel, the source of the Irtis; several lesser ones, the sources of the Jenisca; the great lake Kita, the source of the Oby; another great lake,

lake, the source of the Angara; Lake Baical, which is more than 70 leagues long, and is formed by the river Angara; and Lake Pehu, the source of the Urack, &c. In China and Chinese Tartary, we have Lake Dalai, the source of the great river Argus, which falls into the Amour; the lake of the Three Mountains, the source of the river Helum, which falls likewise into the Amour; the lakes of Cinhal, Cokmor, and Sorama, the sources of the river Hoamho; two large lakes in the neighbourhood of Nankin, &c. In Tonquin is the Guadag, a lake of considerable magnitude. In India, we have Lake Chiamat, which is the source of the river Laquia, and lies near the sources of the Ava, the Longenu, &c. This lake is more than 50 leagues long, and about 40 broad. The source of the Ganges is another lake; and one near Cashmire gives rise to the Indus, &c.

In Africa, there are Lake Cayar, and two or three others, near the mouth of the Senegal; Lake Guarda, and Lake Sigismus, which, together, make a triangular lake of 100 leagues long, and 75 broad, and contain a considerable island. It is in this lake that the Niger loses its name, and, at its exit, assumes that of *Senegal*. In ascending towards the course of this river, we meet with another pretty large lake called *Bour-nou*, where the Niger again changes its name; for the river that falls into this lake is called *Gambaru*. At the sources of the Nile in Ethiopia,

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pia, is the great lake Gambia, which is above 50 leagues long. On the coast of Guiney are also several lakes, which appear to have been originally formed by the sea; and there are few others in Africa of any note.

North America is the country of lakes. The most extensive of them are, Lake Superior, which is about 125 leagues long, and 50 broad; Lake Huron, which is near 100 leagues in length, and about 40 in breadth; Lake Illionois, which comprehending the bay of Puants, is nearly as extensive as Lake Huron; Lake Erie and Lake Ontario, which, together, exceed 80 leagues in length, by 20 or 25 in breadth; Lake Mistafin, to the north of Quebec, is about 50 leagues long; Lake Champlain, to the south of Quebec, is nearly of equal length; Lake Alemipigon, and Lake Christinaux, both to the north of Lake Superior, are likewise considerable; the Lake of Affiniboils contains several islands, and is more than 75 leagues long: Besides the Mexican Gulf, there are two considerable lakes in that country; that called Nicaragua, in the province of the same name, is about 70 leagues in length.

Lastly, in South America, there is a small lake, the source of the Maragnon. A more extensive one gives rise to the river Paraguay: There are, besides Lake Titicares, the waters of which fall into the river Plata, two lesser ones, which discharge their waters into the same river; -

ver ; and some inconsiderable ones in the interior parts of Chili.

All lakes that give rise to rivers, and all those which occur in the course of rivers, or which border upon and discharge their waters into rivers, are not salt. Almost all those, on the contrary, which receive rivers, but give rise to none, are salt. This circumstance seems to favour the opinion, that the saltness of the sea is occasioned by salts brought down from the land by the rivers ; for we find salt does not evaporate ; and, of course, all that is transported by the rivers remains in the sea : Although the water of rivers appears to be fresh, it is well known, that it contains a small quantity of salt, which, in the course of ages, might accumulate to such a degree as would be sufficient to produce the present saltness of the sea, which must be continually augmenting. It is in this manner, I presume, that the Caspian, Lake Aral, and the Black Sea, have become salt. With regard to those seas, which, like marshes, or swamps, neither receive nor discharge rivers, they are either salt or fresh according to their origin. Those in the neighbourhood of the sea are commonly salt ; and those at a distance from it are fresh ; because the former have originated from inundations of the sea, and the latter from fresh fountains.

The waters of the Dead Sea contain a great deal of the bitumen of Judea, which is nothing but

asphaltes; and, accordingly, this sea is often termed the *Asphaltic Lake*. The neighbouring land is impregnated with this bitumen: And many have imagined, that, like the Lake Avernus, no fishes could live in it, and that birds were suffocated in attempting to fly over it. But such dismal effects are produced by neither of these lakes; for both of them contain fishes, the birds fly over them in safety, and men bathe in them with impunity.

It is said, that, in Bohemia, there is a lake, which has holes in it so deep, that they cannot be sounded, and that, from these holes, there issue violent winds which sweep over all Bohemia, and, in winter, raise into the air masses of ice of more than 100 pounds weight*. We are likewise told of a petrifying lake in Iceland; and Lake Neagh in Ireland possesses the same quality. But these petrifications are, doubtless, nothing but incrustations similar to those produced by the waters at Arcueil.

* See Aët. Leipf. anno 1682, p. 246.

P R O O F S
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THEORY OF THE EARTH.

A R T I C L E XII.

Of the Tides.

WATER, like other fluids, naturally descends from the higher to the lower grounds, if not prevented by some interposed obstacle; and, after it has occupied the lowest situation, it remains smooth and tranquil, unless disturbed by some foreign cause. All the waters of the ocean are collected in the lowest places upon the surface of the earth; and hence the motions of the sea must proceed from external causes. The chief motion is that of the tides, which rise and fall alternately, and from which results a general and perpetual motion, in all seas, from east to west. These two motions have an invariable relation to the mo-

tions of the moon. During the full and new moons, this motion from east to west is most remarkable, as well as that of the tides, which ebb and flow, upon most coasts, every $6\frac{1}{2}$ hours: It is always high tide when the moon arrives at the meridian, either above or below the horizon of the place; and it is always ebb or low tide when the moon is at the greatest distance from the meridian, or when it rises and sets. The motion from east to west is perpetual; because, when the tide is rising, the whole ocean moves from east to west, and pushes westward an immense body of water; and the ebbing, or reflux, appears only to be owing to the smaller quantity of water which is then impelled towards the west. The flux, therefore, ought rather to be regarded as a swelling, and the reflux as the subsiding of the waters, which, in place of disturbing the motion from east to west, is the cause that produces and renders it perpetual; though this motion, for the reason already mentioned, is greater during the flux than the reflux.

This motion is attended with the following circumstances: 1st, It is more sensible at the full and new moon than at the quadratures; it is likewise more violent in spring and autumn than in any other season; and it is weakest at the solstices. This phenomenon is occasioned by the combined attractions of the moon and sun. 2^d, The direction and quantity of this motion is

is often varied by the winds, especially such as blow constantly from the same quarter. Great rivers, in like manner, by discharging their water into the sea, produce currents which often extend several leagues, and are strongest when the direction of the wind corresponds with the general motion. Of this an example is afforded in the Pacific Ocean, where the motion from east to west is constant, and very perceptible. 3d, It is worthy of remark, that, when one part of a fluid is moved, the motion is communicated to the whole : During the tides, therefore, a great part of the ocean is sensibly put in motion ; and, consequently, the whole ocean, from surface to bottom, is moved at the same time.

To render this more clear, let us attend to the causes which produce the tides. We formerly remarked, that the moon acted upon the earth by a force which some call attraction, and others gravity. This force penetrates the whole globe, is exactly proportioned to the quantity of matter, and decreases as the squares of the distances increase. Let us next examine what effects this force must produce upon the waters, when the moon comes to the meridian of any place. The surface of the water immediately under the moon is then nearer that planet than any other part of the earth ; of course, that part of the sea must be elevated towards the moon, and the summit of this eminence must be opposite to the moon's centre. To produce this eminence, the

waters upon the surface, as well as those at the bottom, contribute their share, in proportion to their distances from the moon, which acts upon them in the inverse ratio of the squares of their distances. Thus the surface of this part of the sea is first elevated; the surface of the adjacent parts is likewise elevated, but in a smaller degree; and the waters at the bottom of all these parts are raised by the same cause. Hence, as the whole portion of water under the moon is raised, the waters at a distance, upon which no attraction is exerted, must necessarily rush forward with precipitation to supply the place of those which are elevated, or drawn towards the moon. It is in this manner that the flux, or high tide, is produced, which is more or less sensible on different coasts, and which agitates the sea not only at the surface, but at the greatest depths. The reflux, or ebb, is a consequence of the natural disposition of the water, which, when no longer acted upon by the moon, subsides, and returns to occupy those shores from which it had been forced to retire by a foreign power. The same effect is produced when the moon arrives at the antipode, or opposite meridian, but for a different reason: In the first case, the waters rise, because they are nearer the moon than any other part of the globe; and in the second, they rise, because the moon is at the greatest distance from them. It is easy to perceive that the effect must be the same; for, the waters here be-

ing less attracted than those of the opposite hemisphere, they will necessarily recede, and form an eminence, the highest point of which will be where the attraction is least, that is, in the meridian opposite to the moon's station, or to the place where she was thirteen hours before. When the moon comes to the horizon, the tide is ebb, and the sea is in its natural state of equilibrium. But, when she is in the opposite meridian, this equilibrium cannot exist; for the waters, at the place opposite to the moon, being then at their great distance from her, they are less attracted than the rest of the globe; and hence their relative gravity, by which they are constantly kept in equilibrium, pushes them towards the point opposite to the moon, in order to preserve this equilibrium. Thus, in both cases, when the moon is in the meridian of a place, or in the opposite meridian, the waters must be elevated nearly to the same height; and, consequently, they must ebb or flow back when the moon is in the horizon, either at her rising or setting. A motion, such as we have described, necessarily agitates the whole mass of the ocean, from its surface to its bottom; and, as the bottom is less affected by winds than the surface, the motion produced in the former, by the tides, is more regular and uniform.

From this alternate ebbing and flowing, there results, as already remarked, a constant motion of ~~the~~ sea from east to west; for the moon,

which is the cause of the tides, moves from east to west, and, by acting successively in this direction, she draws the waters after her. This motion is most perceptible in straits. At the straits of Magellan, for example, the tides rise near 20 feet, and they continue at this height six hours; but the reflux, or ebbing, lasts only two hours, and the waters run to the west*. This incontestibly proves, that the reflux is not equal to the flux, and that, from both there results a motion to the west, which is stronger during the flux than the reflux. It is for this reason, that, in open seas, at great distances from land, the tides are only rendered perceptible by this general current of the waters from east to west.

The tides are much higher between the tropics than in any other part of the ocean. They likewise rise higher in places that stretch from east to west, in long and narrow bays, and upon coasts which are interrupted with islands and promontories. The highest known tides take place at one of the mouths of the Indus, where they rise 30 feet perpendicular. They have also a remarkable elevation at Malaya, in the straits of Sunda, in the Red Sea, in Nelson's bay, at the mouth of the river St. Lawrence, upon the coasts of China and Japan, at Panama, in the Gulf of Bengal, &c.

* See Narborough's Voyages.

The sea's motion, from east to west, is most observable in particular places. Voyagers have often remarked it in sailing from India to Madagascar and Africa. It moves also with considerable force in the Pacific Ocean, and between the Moluccas and Brazil: But it is most violent in straits: The waters are carried from east to west, through the straits of Magellan, for example, with such rapidity, that their motion is perceptible, at a great distance, in the Atlantic ocean. It was this circumstance, it is said, that made Magellan conjecture that a strait existed by which there was a communication with the two seas. In the straits formed by the Manillas, in the channels between the Maldiva islands, and in the gulf of Mexico, between Cuba and Yucatan, there is a constant current from east to west. This motion, in the gulf of Paria, is so violent, that its strait is called the *Dragon's Mouth*. It is likewise violent in the sea of Canada, in that of Tartary, and in Waigat's straits, through which it forces enormous masses of ice into the northern seas. The Pacific ocean runs from east to west through the straits of Japan; the sea of Japan runs towards China; and the Indian ocean runs westward through the straits of Java, and other islands of India. It is, therefore, evident, that the sea has a general and uniform motion from east to west; and, it is certain, that the Atlantic runs towards America, and that the Pacific

Pacific ocean flies from it,* as is apparent at Cape Current between Lima and Panama*.

In fine, the tides rise and fall alternately in six hours and a half upon most coasts, though they happen at different hours, according to the climate, and the position of particular lands. Thus the coasts of the sea are perpetually beat by the waves; and each tide carries off from the higher grounds small quantities of matter, and deposites them, at a distance, on the bottom of the ocean. In the same manner, each tide carries in, and deposites upon low coasts, sand, shells, and other sea-bodies, which gradually form horizontal strata, and give rise to downs, and little hills, similar to other hills, both in figure and internal structure. Thus the sea is constantly encroaching upon high coasts, and losing ground upon those that are low; and these effects are produced by the tides, and by violent winds.

To give an idea of the violent effects of a stormy sea against a high coast, I shall relate a fact attested by an eye-witness, a person ~~worthy~~ of the highest credit. In the largest of the Orkney islands, there are coasts composed of solid rock, above 200 feet high, and nearly perpendicular to the surface of the water. The tides, as is usual in islands and promontories, rise very high at this place. But, when a violent wind concurs with the flow of the tide, the agitation of the waters is so great, that they often rise

* See Varen. Geogr. p. 119.

above these rocks, and fall down in the form of rain: nay, to this amazing height, gravel, and stones as large as a man's fist, are raised from the foot of the rocks.

I myself saw, in the port of Leghorn, where the sea is much more tranquil, a tempest in December 1731, which obliged the mariners to cut off the masts of their vessels, that were driven, by the violence of the wind, from their anchors in the road: the waters of the sea surmounted fortifications of a great height; and as I was upon one of the most advanced works, before I could reach the town, I was more drenched with sea-water than I could have been by the heaviest rain.

These examples may convey a notion of the violence with which the sea acts against particular coasts. This constant agitation gradually wears*, corrodes, excavates, and diminishes the quantity of the land. All these materials are transported and deposited in places where the sea is more tranquil. In the time of storms, the water is foul and muddy, by the admixture of matters detached from the coasts and from the bottom of the sea. These bodies, which are very vari-

* We are told by Shaw, in his travels, that, in many parts on the coast of Syria and Phœnicia, the rocks had been cut, by the ancients, into troughs of two or three yards long, and broad in proportion, for the purpose of making salt by evaporation. But, notwithstanding the hardness of the rocks, these troughs are now almost totally obliterated by the agitation of the waves.

ous, and carried from great distances, are thrown upon the low shores, especially after tempests, as ambergris on the west of Ireland, yellow amber upon the coasts of Pomerania, cocoas upon the coasts of India, &c. and sometimes pumice, and other singular stones. On this occasion, we may quote a passage from the New Voyages to the islands of America. ‘ When at St. Domingo,’ says the author, ‘ I was presented, among other things, with some light stones, brought in by the sea in high south winds: some of them were two and a half feet long, 18 inches broad, and about a foot thick; and yet they weighed not above five pounds. They were as white as snow, harder than pumice, of a fine grain, and appeared not to be porous. When, however, they were thrown into water, they rebounded like a foot-ball thrown against the ground. It was difficult to force them under water with the hand. I inclosed two of these stones with thin boards, and found that they bore 160 pounds without sinking. They served my negro for a shallop on which he diverted himself in sailing about the quay*.’ This stone must have been a pumice of a close fine grain, which had been transported by the sea from the neighbourhood of some volcano, in the same manner as ambergris, cocoas, common pumice, the seeds of plants, reeds, &c. are transported. It is chiefly on the coasts of Ireland

* Tom. i. p. 260.

and of Scotland that observations of this kind have been made. The sea, by its general motion from east to west, ought to carry to America the productions of our coasts; and it must be by the operation of some irregular movements, that the productions of the East and West Indies, and of the northern regions, are brought upon our coasts. The winds are probably the cause of these effects. In open seas, and at great distances from land, large portions of the water have been seen totally covered with pumice-stones. They could only come from volcanos in islands, or on the continent; and they have probably been transported to the open seas by currents. Before the south part of America was discovered, and when it was not believed that the Indian ocean had any communication with ours, appearances of this kind first gave rise to the suspicion that such a communication was not impossible.

The alternate motion of the tides, and the uniform motion of the sea from east to west, exhibit different appearances in different climates, according to the various indentations in the land, and the height of the coasts. In some places the motion from east to west is not perceptible; at others, it moves in a contrary direction, as on the coast of Guinea. But these contrary motions are occasioned by the winds, by the position of the land, by the waters of great rivers, and by the disposition of the bottom of
the

the sea. All these causes produce currents, which often change the direction of the general movement. But, as this motion from east to west is the greatest, most general, and constant, it ought to produce the most signal effects; and upon the whole, the sea must gradually gain ground on the west, and lose it on the east; and although, upon coasts where the west wind blows during the greatest part of the year, as in France and Britain, the sea may gain land on the east, yet these exceptions destroy not the effect of the general cause.

P R O O F S

OF THE

THEORY OF THE EARTH.

A R T I C L E XIII.

Of Inequalities in the Bottom of the Sea, and of Currents.

THE coasts of the sea may be divided into three kinds: 1. High coasts composed of hard rocks, commonly perpendicular, and of a considerable elevation, rising sometimes to the height of 700 or 800 feet. 2. Low coasts, of which some are almost level with the surface of the water, and others have a small elevation, and are often bordered with rocks nearly of a level with the water, which give rise to breakers, and render the approach of ships exceedingly dangerous. 3. Downs, or coasts formed by sand, either accumulated by the sea, or brought down and deposited by rivers: these
downs

downs form hills of more or less elevation, according to circumstances.

The coasts of Italy are lined with marble and rocks of different species. These rocks appear at a distance like perpendicular pillars of marble. The coasts of France, from Brest to Bourdeaux, consist almost entirely of rocks on a level with the sea, which occasion breakers. The coasts of England, of Spain, and of many other places, are bordered with rocks and hard stones, except particular spots which are employed as roads and harbours.

The depth of the water along the coast is generally proportioned to their elevation; a high coast indicates a deep water; and, on low coasts, the water is commonly shallow. The inequalities at the bottom of the sea near the coasts likewise correspond with the inequalities in the surface of the ground along the shore. This subject is illustrated in the following manner by a celebrated voyager.

‘ I have made it my general observation, that,
 ‘ where the land is fenced with steep rocks and
 ‘ cliffs against the sea, there the sea is very deep,
 ‘ and seldom affords anchor-ground; and, on
 ‘ the other side, where the land falls away with
 ‘ a declivity into the sea, (although the land be
 ‘ extraordinary high within,) yet there are com-
 ‘ monly good foundings, and consequently an-
 ‘ choring; and, as the visible declivity of the
 ‘ land appears near, or at the edge of the water,
 ‘ whether

whether pretty steep, or more sloping, so we
 commonly find our anchor-ground to be more
 or less deep or steep; therefore we come near-
 er the shore, or anchor farther off, as we see
 convenient; for there is no coast in the world,
 that I know, or have heard of, where the land
 is of a continual height, without some small
 valleys or declivities, which lie intermixed with
 the high land. They are the subsiding of val-
 leys or low lands, that make dents in the shore
 and creeks, small bays and harbours, or little
 coves, &c. which afford good anchoring, the
 surface of the earth being there lodged deep
 under water. Thus we find many good har-
 bours on such coasts, where the land bounds
 the sea with steep cliffs, by reason of the de-
 clivities, or subsiding of the land between these
 cliffs: But, where the declension from the hills
 or cliffs is not within land, between hill and
 hill, but, as on the coast of Chili and Peru, the
 declivity is toward the main sea, or into it, the
 coast being perpendicular, or very steep from
 the neighbouring hills, as in those countries
 from the Andes, that run along the shore,
 there is a deep sea, and few or no harbours or
 creeks. All that coast is too steep for anchor-
 ing, and hath the fewest roads fit for ships
 of any coast I know. The coasts of Galicia,
 Portugal, Norway, and Newfoundland, &c.
 are coasts like the Peruvian, and the high
 islands of the Archipelago; but yet not so
 VOL. I. Z scanty

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‘ scanty of good harbours; for, where there are
 ‘ short ridges of land, there are good bays at
 ‘ the extremities of those ridges, where they
 ‘ plunge into the sea; as on the coast of Ca-
 ‘ rracos, &c. The island of Juan Fernandez,
 ‘ and the island of St. Helena, &c. are such high
 ‘ land with deep shore: And, in general, the
 ‘ plunging of any land under water, seems to
 ‘ be in proportion to the rising of its continuous
 ‘ part above water, more or less steep; and it
 ‘ must be a bottom almost level, or very gently
 ‘ declining, that affords good anchoring, ships
 ‘ being soon driven from their moorings on a
 ‘ steep bank; therefore, we never strive to an-
 ‘ chor where we see the land high, and bounding
 ‘ the sea with steep cliffs; and, for this reason,
 ‘ when we came in sight of States-Island, near
 ‘ Terra del Fuego, before we entered into the
 ‘ South-Seas, we did not so much as think of an-
 ‘ choring after we saw what land it was, because
 ‘ of the steep cliffs which appeared against the
 ‘ sea; yet there might be little harbours or coves
 ‘ for shallops, or the like, to anchor in, which
 ‘ we did not see, or search for.

‘ As high steep cliffs bounding on the sea
 ‘ have this ill consequence, that they seldom af-
 ‘ ford anchoring; so they have this benefit, that
 ‘ we can see them far off, and sail close to them,
 ‘ without danger; for which reason we call
 ‘ them bold shores; whereas low land, on the
 ‘ contrary, is seen but a little way, and in many
 ‘ places

‘ places we dare not come near it, for fear of
 ‘ running a-ground before we see it. Besides,
 ‘ there are, in many places, shoals thrown out
 ‘ by the course of great rivers, that from the
 ‘ low land fall into the sea.

‘ This which I have said, that there is usually
 ‘ good anchoring near low lands, may be illus-
 ‘ trated by several instances. Thus, on the
 ‘ south side of the bay of Campeachy, there is
 ‘ mostly low land, and there also is good an-
 ‘ choring all along shore; and, in some places
 ‘ to the eastward of the town of Campeachy,
 ‘ we shall have so many fathom as we are leagues
 ‘ off from land; that is, from 9 or 10 leagues
 ‘ distance, till you come within 4 leagues; and
 ‘ from thence to land it grows but shallower.
 ‘ The bay of Honduras also is low land, and con-
 ‘ tinues mostly so, as we passed along from thence
 ‘ to the coasts of Portobel, and Cartagena, till
 ‘ we came as high as Santa Martha; afterwards
 ‘ the land is low again, till you come towards
 ‘ the coast of Caraccos, which is a high coast
 ‘ and bold shore. The land about Surinam, on
 ‘ the same coast, is low and good anchoring, and
 ‘ that over on the coast of Guiney is such also.
 ‘ And such, too, is the bay of Panama, where
 ‘ the pilot-book orders the pilot always to found,
 ‘ and not to come within such a deep, be it by
 ‘ night or day. In the same seas, from the high
 ‘ land of Gautimala in Mexico, to California,
 ‘ there is mostly low land and good anchoring.

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‘ In the main of Asia, the coast of China, the bay of Siam and Bengal, and all the coast of Coromandel, and the coast about Malacca, and against it the island of Sumatra, on that side, are mostly low anchoring shores. But, on the west side of Sumatra, the shore is high and bold; so most of the islands lying to the eastward of Sumatra; as the islands Borneo, Celebes, Gilolo, and abundance of islands of less note, lying scattered up and down those seas, are low land, and have good anchoring about them; with many shoals scattered to and fro among them; but the islands lying against the East-Indian Ocean, especially the west sides of them, are high land and steep, particularly the west parts, not only of Sumatra, but also of Java, Timor, &c. Particulars are endless; but, in general, ’tis seldom but high shores and deep waters, and, on the other side, low land and shallow seas are found together*.’

It is, therefore, fully established by the observations of navigators, that there are in the bottom of the sea, considerable mountains, and other inequalities. We are also assured by the testimony of divers, that there are smaller inequalities occasioned by rocks, and that the cold is greatest in the hollows or valleys. In general, as formerly remarked, the depths of open seas augment in proportion to their distance from the coasts. It appears, from M. Buache’s chart of that part of the ocean which lies be-

* Dampier’s Voyages, vol. i. p. 422, 423, 424, 425. •

tween the coasts of Africa and America, and from the draughts he has given us of the sea from Cape Tagrin to Rio-grand, that the bottom of the ocean is as irregular as the surface of the land; that abrolhos, where there are *vigies*, and where some of the rocks are on a level with the water, are only the tops of large and high mountains, of which Dolphin island is one of the most elevated points; that the Cape de Verd islands are likewise the tops of mountains; and that all round these abrolhos and islands, the depth of the sea is unfathomable.

With regard to the qualities of the different soils at the bottom of the sea, little can be said with precision, as all our knowledge is derived from sounding and from divers. We only know, that some places are covered with slime and mud of a considerable thickness, in which anchors can have no hold: It is probable that, in these places, the mud is deposited by rivers. Other parts are covered with sand of different kinds, similar to those upon land. In others are heaps of shells, madrepores, corals, and other productions of insects, just beginning to unite and to assume the form of stones: In others, we find fragments of stones, gravel, and frequently stones and marbles completely formed. In the Maldiva islands, for example, they build their houses with a hard stone raised from some fathoms under water. At Marfeilles very good marble is raised from the bottom of the

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sea, which, instead of wasting or destroying stones and marble, creates and preserves them: It is the sun, the earth, the air, and the rains, which alone corrupt and destroy these substances.

The bottom of the sea must be composed of the same materials as the surface of the earth, since the very same substances are found on both. At the bottom of some parts of the ocean are vast collections of shells, madrepores, and corals; and we find, upon land, numberless quarries, banks of chalk, and of other substances, mixed with the same shells, madrepores, and corals; so that, in every view, the dry parts of this globe resemble those covered with the waters, both in composition of materials, and in superficial inequalities.

To these inequalities at the bottom, we must ascribe the origin of currents; for, if the bottom were uniform and level, there could be no current but the general motion from east to west, and such as might occasionally be produced by the winds. But what incontestibly proves, that most currents are produced by the tides, and take their direction from inequalities at the bottom, is, that they uniformly follow the tides, and change their course at every ebb and flow*. This fact is confirmed by the testimony

* See Pietro della Valle on the currents in the Gulf of Cambraya, vol. vi. p. 363.

of all navigators, who unanimously affirm, that, in those places where the tides are most impetuous, the currents are likewise most rapid.

Thus it is apparent, that the tides give rise to currents, and that they always follow the direction of the opposite hills or mountains between which they run. Currents produced by winds likewise observe the direction of the eminences concealed under the waters; for they seldom run in the direct path of the winds; neither do those produced by the tides invariably observe the course pointed out by their original cause.

To give a distinct idea of the origin of currents, let it be remarked, that they take place in all seas; that some are rapid, and others flow; that some are of great extent both in length and breadth, and others shorter and narrower; that the same cause by which they are produced, whether it be the winds or the tides, frequently bestows on each a difference both in celerity and direction; that a north wind, for example, which ought to produce a general motion towards the south, gives rise, on the contrary, to a number of separate currents, very different, both in their direction and extent, some running south, others south-east, and others south-west; some are rapid, others flow; some long and broad, and others short and narrow: In a word, their motions are so various and combined, that they lose all resemblance to their

general cause. When a contrary wind blows, every motion is uniformly reversed; and the course of the different currents is precisely the same as would necessarily take place between two opposite and neighbouring hills upon the surface of the land, were it covered with water. Of this, the Maldiva and Indian islands, where the winds blow and the currents run regularly for six months in opposite directions, afford most striking examples. The same thing has been remarked of currents between shoals and sand-banks. In general, all currents, from whatever cause they proceed, have the same dimensions, and the same direction through their whole course; but they differ greatly from each other in every respect. This uniformity and variety can proceed from no other cause but the inequalities of the hills, mountains, and valleys, at the bottom of the ocean; for, it is an established fact, that the current between two islands follows the direction of the coasts; and the same phenomenon is exhibited between shoals and sand-banks. The hills and mountains in the sea, therefore, may be considered as the banks which contain and direct the currents; Hence a current is a river, the breadth of which is determined by that of the valley through which it runs; its rapidity is proportioned to the force by which it is produced, combined with the breadth of the interval through which it passes; and its direction is marked out by the position.

position of the hills and other inequalities between which it shapes its course.

An opportunity is now afforded us of explaining that singular correspondence between the angles of hills and mountains, which is observable in every country of the world. We have already remarked this uniform correspondence of angles in the banks of rivers. The cause of this effect depends on the laws of hydrostatics, and might be easily explained. But it is sufficient for our present purpose, that the fact is general, and universally known; and every man may satisfy himself with his own eyes, that, when the bank of a river projects into the land, to the left, for instance, the opposite bank, on the contrary, makes a projection from the land on the right.

The currents of the ocean, therefore, which ought to be regarded as large rivers, and as subject to the same laws as those on land, must, like them, have formed, through the whole extent of their course, many sinuosities or windings with corresponding angles or projections: And, as the banks of currents are hills and mountains, either above or below the surface of the water, they must have produced on these eminences the same effects as our rivers do upon their banks. Thus, we have no longer any reason to be astonished, that ~~our~~ hills and mountains, which were formerly covered with the sea, and formed by the sediments of its waters,

ters, should have assumed, by the motion of its currents, this regular figure, arising from the correspondence of their opposite angles. They were originally banks of currents, or of sea-rivers, and must necessarily have assumed a figure and direction similar to those of land-rivers.

This alone, independent of the other proofs which we have adduced, is sufficient to show, that all our present continents and islands were formerly covered with the waters of the ocean, and throws much light on the theory which I have been endeavouring to establish. It was not enough to have proved that the internal strata of the earth were formed by sediments of the waters; that the mountains were elevated by successive accumulations of these sediments; or, that many strata were impregnated with shells and other productions of the sea. It was still necessary to investigate and assign the real cause of the correspondence in the angles of mountains, which hitherto had never been attempted, but which, when united with the other proofs, forms a connected chain of evidence in support of my theory, as complete as the nature of physical reasoning will admit.

The most conspicuous currents of the ocean are those in the Atlantic near the coast of Guiney. They extend from Cape Verd to the bay of Fernandpo. They run from west to east, which

which is contrary to the general motion of the sea; and they are so rapid, that vessels sail in two days from Moura to Rio de Benin, about 150 leagues, but require six or seven weeks to return. It would be impossible to clear these latitudes, were it not by means of the tempestuous winds which suddenly arise in them: But there are sometimes whole seasons in which the mariner is obliged to remain stationary, on account of perpetual calms, the sea having here no motion but what it derives from the currents; and these always run in upon the coasts, from which they extend not above 20 leagues. Near the island of Sumatra, there are rapid currents, which run from south to north, and which have probably given rise to the bay, between Malacca and India. We find similar currents between Java and the lands of Magellan, and between the Cape of Good Hope and Madagascar, especially on the African coast from Natal to the Cape. In the Pacific Ocean, upon the coasts of Peru, and the rest of America, the waters move from south to north, which is probably owing to the constant blowing of the south wind. The same motion from south to north has been remarked on the coasts of Brasil, from Cape St. Augustine to the Antilles, and from the mouth of the Manilla Straits to the Philippines and Japan*.

* See Varen. Geogr. p. 140.

There are violent currents in the neighbourhood of the Maldiva islands; and between these islands, as already observed, the currents run alternately in opposite directions six months in the year, and are probably occasioned by the trade-winds.

We here enumerate such currents only as are remarkable both for their extent and their rapidity; because the number of lesser currents is almost infinite. The tides, the winds, and every cause that agitates the waters, produce currents, which are more or less perceptible in different places. We have already remarked, that the bottom of the sea is, like the land, intersected with mountains and valleys, shoals and sand-banks. In all the mountainous places, the currents must necessarily be violent; and, where the bottom is smooth and level, they are almost imperceptible; for the rapidity of a current must augment in proportion to the obstacles with which the waters have to encounter. The current between two chains of mountains will be more or less violent in proportion to their distance. The same thing must happen between two banks of sand, or two adjacent islands. It is, accordingly, remarkable, that in the Indian ocean, which is intersected with an innumerable quantity of islands and sand-banks, there are every where currents, which, by their rapidity, render navigation extremely dangerous.

Currents are not only occasioned by inequalities at the bottom, but a similar effect is produced by the coasts, from which the waters are repelled to greater or less distances. This regorging of the waters may be rendered perpetual and violent by particular circumstances: An oblique position, for example, of a coast, its contiguity to a bay or a great river, a promontory, or any particular obstacle to the general movement of the waters, will always give rise to a current: Now, as nothing is more irregular than the bottom and the coasts of the sea, the number of currents which every where appear ought not to create surprise.

All currents have a determinate breadth, proportioned to the interval between the two eminences which limit them. They run in the same manner as land-rivers; they form a channel, and cut their banks in a regular manner, with corresponding angles: In fine, the currents of the ocean have scooped out our valleys, shaped our mountains, and bestowed upon the land, while it remained under the surface of the waters, the form in which it now appears.

If any doubt should remain concerning the correspondence in the angles of mountains, I appeal to the testimony of every man's observation. Every traveller may remark this correspondence in opposite hills. When a hill makes a projection to the right, the opposite one uniformly recedes to the left. Besides, in opposite hills

hills separated by valleys; there is rarely any difference in their height. The more I observe the contours and elevations of hills, I am the more convinced of the correspondence of their angles, and of their resemblance to the channels and banks of rivers. It was the repeated observation of this surprising regularity and resemblance that first suggested the idea of the theory of the earth which I am now supporting. When to this are added the parallelism of the strata, and the shells so universally incorporated with different materials, no subject of this nature can admit of a greater degree of probability.

P R O O F S

O F T H E

T H E O R Y O F T H E E A R T H.

A R T I C L E XIV.

Of Regular Winds.

IN our climates, nothing can appear to be more capricious and irregular than the force and direction of the winds. But there are some countries where this irregularity is not so great, and others where the wind blows constantly in the same direction, and with nearly the same degree of force.

Though the motions of the air depend on many causes; yet there are some more constant and powerful than others. But it is difficult to estimate their precise effects, because these are often modified by secondary causes.

The heat of the sun is the most powerful cause of winds: It produces a considerable and successive

ſucceſſive rarefaction in the different parts of the atmofphere, and gives riſe to an eaſt-wind, which blows conſtantly between the Tropics, where the rarefaction is greateſt.

The force of the ſun's attraction upon the atmofphere, and even that of the moon, are inconfiderable, when compared with the cauſe juſt mentioned. This force, it is true, produces a motion in the air ſimilar to that of the tides in the ſea: But, though the air is elastic, and 800 times lighter than water, the motion produced by attraction cannot exceed what is excited in the waters of the ocean by the ſame cauſe; for the action of gravity being proportioned to the quantity of matter, it muſt elevate a ſea of water, of air, or of quickſilver, nearly to the ſame height. Hence the influence of the planets upon the air muſt be inconfiderable*; and, though it muſt occaſion a ſlight motion from eaſt to weſt, this motion becomes altogether inſenſible when compared with that produced by the heat of the ſun: But as the rarefaction is always greateſt when the ſun is in the zenith, the current of air muſt follow the courſe of the ſun, and produce a conſtant wind from eaſt to weſt. At ſea, this wind blows perpetually in the Torrid Zone, and at land, in moſt

* See *Reſſections ſur la Cauſe Generale des Vents*, par M. D'Alembert.

places between the Tropics. It is this wind which we perceive when the sun rises ; and, in general, east winds are more frequent, and more violent, than west winds. The general wind, from east to west, extends even beyond the Tropics. It blows so constantly in the Pacific ocean, that the ships coming from Acapulco to the Philippines, perform their voyage, which is more than 2700 leagues, without the least danger, and almost without the necessity of being directed. In the Atlantic, between Africa and Brasil, this wind is equally constant. It is likewise felt between the Philippines and Africa ; but there it is less constant, on account of the obstacles it meets with from the numerous islands in that sea ; for it blows, during the months of January, February, March and April, between the Mozambique coast and India ; but it gives place to other winds during the rest of the year : And, though it is less perceptible on the coasts than on the open sea, and still less in the interior parts of continents than on the coasts, yet, in some places, it blows almost perpetually, as on the east coasts of Brasil, of Loango in Africa, &c.

This wind is constant under the Line ; and, therefore, in going from Europe to America, mariners direct their course southward, along the coasts of Spain and Africa, till they come within 20 degrees of the Equator, where they fall in with the east, or trade-wind, which car-

ries them directly to the coast of America. By means of the same wind, the voyage from Acapulco to the Philippines is performed in two months; but the return from the Philippines to Acapulco is much more difficult, and requires a longer time. About 28 or 30 degrees on this side of the Line, the west wind is equally constant; and, for this reason, the vessels returning from the West Indies to Europe, observe not the same route as in going out. Those from New Spain run north, along the coast till they arrive at the Havannah, in the island of Cuba; and from thence they proceed northward till they fall in with the west wind, which carries them to the Azores, and then to Spain. In the same manner, vessels returning by the South Sea from the Philippines or China, to Peru or Mexico, sail north as far as Japan; and, under that latitude, they proceed till they arrive at a certain distance from California; and from thence, following the coast of New Spain, they reach Acapulco. These east winds blow not always from the same point; but, in general, they blow from the south-east, from April to September, and from the north-east from November to April.

The east wind, by its constant action, augments the general motion of the sea from east to west. It also produces perpetual currents, some of them running from east to west, and others from east to south east, or north-west, according to the direction of the eminences, or chains

chains of mountains, below the surface: The valleys or intervals between them serve as channels to these sea-rivers. The variable winds which blow sometimes from the east, and sometimes from the south, likewise produce currents, which change their direction with that of the wind.

The winds that blow constantly for some months are commonly succeeded by contrary winds, which oblige the mariner to wait for that which is most favourable to his destination. When these winds change, they often produce, for several days, and sometimes for a month, or even two months, a perfect calm, or dreadful tempests.

These general winds, occasioned by the rarefaction of the atmosphere, are variously combined and modified by different causes, and in different climates. In that part of the Atlantic which lies under the Temperate Zone, the north wind blows almost constantly during the months of October, November, December, and January. These months, therefore, are most favourable for ships going to the Indies, which are carried over the Line by this wind: And it is a well known fact, that vessels which depart from Europe in March, frequently arrive not sooner at Brasil than those which set out in the following October. The north wind reigns almost perpetually, during the winter, off Nova Zembla, and other northern coasts. At Cape de Verd, the

south wind blows, during the month of July, which is the rainy season, or winter, in that climate. At the Cape of Good Hope, the north-west wind blows during the month of September: The same wind blows at Patna in the East Indies, during the months of November, December, and January, and occasions great rains; but the east wind prevails during the other nine months. In the Indian Ocean, between Africa and India, and as far as the Molucca islands, the trade-wind from east to west reigns from January to the beginning of June; the west winds begin in August or September; and, in the interval between June and July, there are dreadful tempests, generally from the north winds; but these winds are more variable on the coasts than in the open seas.

In the kingdom of Guzarat, and upon the neighbouring coasts, the north winds blow from March to September; and, during the other months, the south winds almost always prevail. The Dutch, in returning from Java, set out in January or February, by the assistance of the east wind, which is felt as far as the 18th degree of south latitude; and then they meet with south winds, which carry them to St. Helena*.

Some regular winds are produced by the melting of the snows. This was remarked by the ancient Greeks. During summer, a north-east wind, and a south-east one during winter,

* See Varen. Geogr. cap. 20.

was observed to take place in Thracia, in Macedonia, in the Egean Sea, and even in Egypt and Africa; and winds of the same kind have been remarked in Congo, at Guzarat, and at the extremity of Africa, which are all occasioned by the melting of the snows. Regular winds, which last but a few hours, are also produced by the motion of the tides; and, in many places, as on the coasts of New Spain, of Congo, of Cuba, &c. a wind blows from the land during the night, and from the sea during the day.

The north winds, are equally regular within the polar circles; but they become more and more imperceptible as we approach the Equator: This remark is applicable to both poles.

In the Atlantic and Ethiopic ocean, within the tropics, an east wind blows during the whole year, without any considerable variation, except in some small spots, where it changes according to the situation of coasts, and other circumstances: 1st, Near the coast of Africa, and about the 28th degree of north latitude, vessels are certain of finding a fresh gale from the north-east, or north-north-east, which accompanies them to the 10th degree of the same latitude, about 100 leagues from the coast of Guinea; and at the 4th degree of north latitude, they meet with calms and tornado's. 2^d, In going by the Caribbee islands, this wind turns more and more easterly, in proportion as vessels approach the American coast. 3^d, The limits

limits of these variable winds, in the Atlantic, are more extensive upon the coasts of America than upon those of Africa. Along the coast of Guinea, from Sierra Leona to the island of St. Thomas, an extent of about 500 leagues, there is a perpetual south, or south-west wind. The narrowest part of the Atlantic is from the coast of Guinea to Brasil, where it is not above 500 leagues over. Vessels, however, that depart from Guinea, are obliged to shape their course southward, especially when they set out in the months of July or August, in order to fall in with the south-east winds, which blow constantly during this season*.

In the Mediterranean, the east wind blows from the land in the evening, and the west wind from the sea in the morning. The south wind, which is accompanied with rain, and blows commonly during the latter end of autumn, at Paris, in Burgundy, and Champagne, yields to a mild north-east wind, which produces that fine weather vulgarly called Saint Martin's Summer†.

Doctor Lister alledges, that the east wind, which reigns during the whole year between the tropics is occasioned by the transpiration of the plant called the *sea-lentil*, which abounds in these climates; and that the difference of land-winds is owing to the different situation of trees

* See Phil. Trans. Abridg. vol. ii. p. 129.

† See Traité de eaux de M. Mariotte.

and forests. This ridiculous whim he assigns as the cause of the winds; and, in his opinion, the wind is strongest at mid-day, because the transpiration from plants is then greatest; and the wind, continues he, blows from east to west, because all plants are, in some measure, sun-flowers, and transpire most from the side opposed to the sun*.

Other authors have assigned the diurnal motion of the earth as the cause of this east wind. This notion is specious: But every man, who has the least knowledge of physics, must allow, that no fluid which surrounds the earth can be affected by its rotation; that the air must move along with the earth itself; and that the rotatory motion is equally imperceptible in the atmosphere as on the surface of the earth.

The principal cause of the winds, as already remarked, is the heat of the sun†; for, whatever rarifies or condenses the air, must produce a wind, or current, in a direction opposite to those places where the rarefaction or condensation is greatest.

The pressure of clouds, exhalations from the earth, the explosion of meteors, rains, &c. likewise produce considerable agitations in the atmosphere. Each of these causes, when variously combined, produce different effects. As it is in vain to attempt a complete theory of the winds, I confine myself to their history.

* See Phil. Trans. No. 156.

† See Halley's Treatise on this subject in the Phil. Trans.

If we had a series of observations upon the direction, the force, and the variations of the winds in the different climates of the earth, and if these observations were sufficiently numerous and exact, we might be enabled to form more complete ideas with regard to the causes of the different changes in the atmosphere.

The winds are more regular at sea than upon land; because their motion is not interrupted. But, upon land, the direction is frequently changed by the interposition of mountains, forests, cities, and other obstacles. Winds are often reflected from mountains with a force nearly equal to that of their original current: These winds are exceedingly irregular, because their direction depends on the contour, the height, and the situation of the mountains from which they rebound. The sea-winds also blow with more force and uniformity, and last longer: The land-winds, however violent, have intermissions, and moments of repose: But, at sea, the current of the air, having no obstacles to contend with, is uniform and perpetual.

At sea, the east winds, and those which come from the Poles, are generally stronger than the west winds, and those that proceed from the Equator. But, at land, the south and west winds are more or less violent, according to the different situation of particular countries. During spring and autumn, the winds, both at sea and land, are more violent than in summer or winter,

ter. For this fact, several reasons may be assigned :

1. In spring and autumn the tides are highest ; and, consequently, the winds they excite are most violent during these seasons : 2. The motion produced in the atmosphere by the action of the sun and moon, or the tides of the air, must likewise be greatest about the equinoxes : 3. The melting of the snows in spring, and the condensation of the vapours exhaled in summer by the sun, and which fall down in the autumn in the form of rain, produce, or, at least, augment the force of the winds : 4. The transition from heat to cold, or from cold to heat, must create considerable augmentation and diminution in the volume of the air, which alone is sufficient to raise great winds.

Contrary currents in the atmosphere have often been remarked. We see some clouds moving in one direction, and others, either above or below them, proceeding in a direction perfectly opposite. This contrariety of motion never continues long ; because its general cause is the resistance of some large cloud, which reflects the wind in a direction opposite to its natural course, but is soon dissipated.

The winds are more violent in proportion to the elevation of the ground, till it arrive at the ordinary station of the clouds, which is about one-fourth or one-third of a league perpendicular height ; and, beyond this, the sky is generally serene, especially in summer, and the wind gradually

gradually diminishes : It is even said to be altogether imperceptible on the tops of the highest mountains. However, as the summits of these mountains are covered with ice and snow, it is natural to think that this region of the air is agitated during the fall of the snows, and that the winds are imperceptible in the summer season only. The light vapours which are raised in summer fall in the form of dews ; but, in winter, they are condensed, and fall on the tops of the mountains in the form of snow or ice, which may raise considerable winds at that altitude.

The celerity of a current of air is augmented when its passage is contracted. The same wind, which is but slightly felt in a large open plain, becomes violent in its progress through a narrow pass in a mountain, or between two high houses ; and it is most violent at the tops of the buildings or of the mountain, because the air, being compressed by these obstacles, is augmented both in volume and density ; and, as its celerity remains the same, its force or momentum must be increased. It is for this reason that the wind appears to be more violent near a church or a tower than at a distance from them. I have often remarked, that the wind reflected from a building standing by itself, is stronger than the direct wind by which it was produced. This effect can be owing to no other cause than the compression of the air against the building from which it rebounds.

As the density of the air is greatest at the surface of the earth, it is natural to conclude, that the wind must there also be most violent; and this conclusion is, I apprehend, just, when the sky is serene: But, when it is charged with clouds, the action of the wind will be most violent at the height of the clouds, which are denser than air, as they fall in the form of rain or of hail. In computing the force of wind, therefore, we ought to estimate not only its velocity, but likewise the density of the air; for two winds, of equal velocities, may differ greatly in their force, if the densities of the air be unequal. From this remark, we may learn the imperfection of those machines which have been employed for measuring the velocity of the winds.

Particular winds, whether they be direct or reflected, are more violent than those which are general. The interrupted action of land-winds depends on the compression of the air, which renders every blast more violent than if the current were uniform. A uniformly continued stream of air produces not such havoc as the fury of those winds which blow, as it were, by paroxysms. But of this we shall treat more fully in the next article.

The winds, in their various directions, may be considered under general points of view, from which, perhaps, some useful deductions may be drawn. For example, the winds may be divided into Zones. The east wind, which extends

extends 25 or 30 degrees on each side of the Equator, exerts its force round the globe within the Torrid Zone. The north wind blows with equal constancy in both the Frigid Zones. Thus, the east wind occupies the Torrid Zone, and the north wind the Frigid Zones. With regard to the Temperate Zones, the winds peculiar to them may be considered only as currents of air, produced by the combination of the two principal winds, which give rise to all those that come from the eastern points; and the west winds, which are common in the Temperate Zones, both in the Pacific and Atlantic Oceans, may be considered as reflections from the continents of Asia and America, but deriving their origin principally from the east and north winds.

Though we have said, that, generally speaking, the east wind blows round the globe 25 or 30 degrees on each side the Equator; yet it must be acknowledged that, in some places, it extends not so far, and that its direction is not throughout from east to west; for, on this side of the Equator, it is east-north-east, and, beyond the Equator, it is east-south-east; and, the more we recede from the Equator, its direction is the more oblique. The Equator is the line under which the direction of the wind from east to west is most exact. In the Indian Ocean, for example, the general wind from east to west extends not above 15 degrees beyond the Equator. In going from Goa to the Cape of Good Hope,
this

this wind is not felt beyond the 12th degree of south latitude, nor is it perceptible on this side of the Equator. But, after arriving at the 12th degree of south latitude, this wind continues to the 28th degree. In the sea which separates Africa from America, there is an interval from the 4th degree of north latitude to the 10th or 11th of south latitude, where this general wind is not perceived. But, beyond the 10th or 11th degree, it extends to the 30th.

There are likewise many deviations in the trade-winds, which have an alternate motion. Some continue for a longer or shorter time; others have a greater or lesser extent; others are more or less regular, and more or less violent. The following, according to Varenus, are the principal phænomena of these winds: ‘ In the ocean between Africa and India, and as far as the Molucca islands, the east wind commences in January, and continues to the beginning of June. In the month of August, the west wind begins, and continues for three or four months. In the interval between these trade-winds, which is from the end of June to the beginning of August, the sea is infested with violent tempests from the north.

‘ These winds are subject to the greatest variations near the coasts: Vessels cannot take their departure from the coast of Malabar, and other ports on the west coast of the peninsula of India, to Africa, Arabia, or Persia, but from
 10 the

‘ the month of January to April or May ; for,
 ‘ at the end of May, and during the months of
 ‘ June, July, and August, the tempests from
 ‘ the north and north-east are so violent, that
 ‘ no ships can keep the seas. But, on the
 ‘ other side of this peninsula, in the sea which
 ‘ washes the coast of Coromandel, there are no
 ‘ tempests of this kind.

‘ Vessels depart from Java, Ceylon, and several other places, for the Molucca’s in September, because the west wind begins then to blow in these regions. However, when 15 degrees south of the Equator, this wind ceases, and they fall in with the trade-wind, which, in this place, blows from the south-east. In the same manner, vessels depart from Cochin for Malacca in March ; because, at this time, the west wind begins to blow. Thus the west winds arise at different times, in different parts of the Indian Ocean. The times of departure are different from Java to the Molucca’s, from Cochin to Malacca, from Malacca to China, and from China to Japan.

‘ At Banda, the west winds terminate at the end of March ; calm and variable winds occupy the month of April ; and the east winds begin with great violence in May. At Ceylon, the west winds commence about the middle of March, and continue to the beginning of October, when the east, or rather east-north-east winds, return. At Madagascar, they have
 ‘ north

north or north-west winds from the middle
 of April to the end of May; but east and
 south winds in February and March. From
 Madagascar to the Cape of Good Hope, the
 northerly winds prevail during the months of
 March and April. In the gulf of Bengal, af-
 ter the 20th of April, the south winds blow
 with violence; and, before this period, the
 south-west and north-west winds prevail. The
 westerly winds are also violent in the Chinese
 sea during the months of June and July. This
 is, therefore, the most proper season for sail-
 ing from China to Japan: But, in returning
 from Japan to China, February and March are
 preferable, because the easterly winds then
 prevail.

There are some winds which may be con-
 sidered as peculiar to certain coasts: For ex-
 ample, a south wind blows almost perpetually
 on the coasts of Chili and Peru. It begins
 about the 46th degree of south latitude, and ex-
 tends beyond Panama, which makes the voy-
 age from Lima to Panama more easy and ex-
 peditious than the return. The westerly winds
 blow almost continually on the coasts of Ma-
 gellan's land, in the neighbourhood of the
 straits of La Maire. Upon the Malabar coast,
 they have almost constantly north and north-
 west winds. The north wind is very frequent
 on the coast of Guinea. The westerly winds
 reign

‘ reign upon the coasts of Japan during the months of November and December.’

The periodic, or alternate winds, mentioned above, are peculiar to the sea. But, upon land there are also periodic winds, which return at certain seasons or particular days, or even at stated hours. On the coast of Malabar, for example, an easterly land-wind blows from September to April: It generally commences at midnight, and ends at noon; and it is not perceptible at 12 or 15 leagues from the coast. From noon to midnight, there is a gentle westerly breeze from the sea. Upon the coasts of New Spain in America, and upon those of Congo in Africa, land-winds blow during the night, and sea-winds during the day. Winds blow from all the coasts of Jamaica during the night, which prevents the landing, or sailing of ships, with safety, before the rising of the sun.

In winter, the port of Cochin is inaccessible; neither can any vessel get out; because the winds are so impetuous, that no vessels can keep the sea; and, besides, the west wind, which blows with great fury, drives such a quantity of sand into the mouth of the river, as renders it impossible for ships of any burthen to enter it for six months of the year. But the east wind, which blows during the other six months, drives back the sand into the sea, and opens the mouth of the river. At the straits of Babelmandel, there is a south-east wind, which is regularly succeeded

ceeded by the north-east. At Saint Domingo, there are two different winds that rise regularly every day; the one, which is from the sea, comes from the east, and begins at 10 o'clock before noon; the other, which is a land wind, from the west, rises at 6 or 7 in the evening, and continues the whole night. Other facts of this kind, collected from voyagers of knowledge and credit, might furnish a complete history of the winds, which would be a work extremely useful both in navigation and physics.

P R O O F S

OF THE

THEORY OF THE EARTH.

ARTICLE XV.

*Of Irregular Winds, Hurricanes, Water-Spouts,
and other Phænomena, occasioned by the agita-
tions of the Sea, and of the Air.*

THE winds are more irregular on the land than on the sea, and in high than in low countries. The mountains not only change the direction of the winds, but even produce some, which are either constant or variable according to their causes. The melting of snows on the tops of mountains generally give rise to constant winds, which last a considerable time. The vapours that strike against the mountains, and accumulate upon them, produce variable winds, which are very common in all climates; and there is as great a variety in the motions of the

the air, as there are inequalities on the surface of the earth. We can, therefore, give examples only, and a genuine history of facts: And, as a connected series of observations upon the variations of the winds, and even of the seasons, in different countries, is still wanting, we shall not attempt to explain all the causes of these variations, but shall confine ourselves to those which are most probable.

In straits, at the extremities of promontories, peninsulas, and capes, and in all narrow bays, tempestuous winds are frequent. But, independent of these, some seas are much more infested with storms than others. The Indian Ocean, the seas of Japan and of Magellan, along the African coast beyond the Canaries, and the opposite coast near Natal, and the Red and Vermilion Seas, are all subject to tempests. The Atlantic is likewise more tempestuous than the great ocean called the Pacific: This last ocean, however, is no where perfectly tranquil, except between the Tropics; for the nearer we approach the Poles, it is the more subject to variable winds, the sudden changes of which produce tempests.

All continents are subject to the effects of variable winds, which are sometimes very singular. In the kingdom of Cassimir, which is surrounded with the mountains of Caucasus, a most sudden reverse of seasons is felt on Mount Pirepenjale. In less than an hour's journey, we pass from summer to winter: A north and a south
 B B 2 wind,

388 OF IRREGULAR WINDS, &c.

wind, according to Bernier, blow perceptibly within 200 paces of each other. The position of this mountain must be singular; and, therefore, it merits a particular examination. In the peninsula of India, which is traversed from north to south by the mountains of Gats, the extreme heats of summer are felt on one side of these mountains, and all the rigours of winter on the other. The same phenomenon takes place on the two opposite coasts of Cape Rosalgate in Arabia: On the north coast the sea is calm and tranquil; while the south coast is infested with continual storms. Ceylon exhibits another example of this phenomenon. Winter and high winds reign in the north part of the island, while, on the south side of it, fine weather and summer heats prevail. Of opposite seasons in the neighbourhood of each other, and at the same time, there are several examples, not only on the continent, but on the islands, as at Cerem, a long island near Amboyna, in the north part of which it is winter, and summer in the south part; and the interval between these two seasons is not above three or four leagues.

In Egypt a south wind prevails during summer, which is so hot as to stop respiration; and it raises such immense quantities of sand, that the sky seems to be covered with thick clouds. This sand is so fine, and is blown with such violence, that it penetrates the closest chests. When this wind continues for several days, it gives rise
to

to epidemic diseases, which frequently cut off vast numbers of men. It seldom rains in Egypt; every year, however, there are some days of rain in the months of December, January, and February. But thick fogs are more frequent than rain, especially in the neighbourhood of Cairo. These fogs commence in November, and continue during the winter; and, through the whole year, even when the sky is serene, the dews fall so copiously, that they have all the effects of rain.

In Persia, the winter commences in November, and lasts till March. The cold is strong enough to produce ice; and snows fall in the mountains, and sometimes in the plains. From March to May, there are violent winds, which recal the warmth of summer. From May to September the sky is serene, and the heats are moderated during the night by fresh breezes which continue till morning; and, in autumn, there are violent winds, like those which blow in the spring. However, though these winds are very strong, they seldom produce tempests or hurricanes. But, in summer, a very noxious wind blows along the Persian Gulf, which is called *Samiel* by the natives; it is still hotter and more terrible than that of Egypt; and, as it acts like an explosion of inflamed vapour, it suffocates every person who unhappily falls within its vortex. A similar ~~wind~~ rises in summer along the Red Sea, which suffocates animals, and transports

transports such quantities of sand, that many people imagine this sea will, in the course of time, be completely filled up. Arabia gives birth to frequent clouds of sand which darken the air, and excite dangerous whirlwinds. At Vera Cruz, when the hot winds blow from the north, the houses of that town are almost buried with sand. Hot winds are also felt in summer at Negapatan in India, and likewise at Petapouli and Masulapatan. These scorching winds which kill men are fortunately of no long duration; but they are extremely violent, and their heat and deleterious quality are proportioned to their velocity, which is contrary to the nature of other winds; for the more their rapidity, they are the more wholesome and refreshing. This difference proceeds from the degree of heat in the air. When the heat of the air is less than that of the body, the motion of the air is agreeable. But, when the heat of the air is greater than that of the bodies of animals, its motion scorches and suffocates. At Goa, the winter, or rather the rainy and tempestuous season, is in the months of May, June, and July, and it cools and refreshes the air, which would otherwise be perfectly insupportable in that region.

The Cape of Good Hope is famous for its tempests, and a peculiar cloud which produces them. This cloud at first appears like a small round spot in the heavens, which mariners distinguish

distinguish by the name of the *Ox's Eye*. The
 seeming smallness of this cloud is probably owing
 to its great height. Of all voyagers who
 mention this cloud, Kolbe appears to have examined
 it with the greatest attention. 'This
 cloud,' says he*, 'which appears on the moun-
 tains of the *Table*, or of the *Devil*, or of the
Wind, is composed, if I am not deceived, of an
 infinite number of particles pushed, in the first
 place, against the mountains to the east of the
 Cape, by the east wind which blows in the
 Torrid Zone during almost the whole year.
 These particles or vapours are stopped by the
 high mountains, and are collected on their
 east side. They then become visible in the
 form of small fragments of clouds, which, by
 the constant action of the east wind, are ele-
 vated to the tops of the mountains. Here
 they remain not long at rest; but, being forced
 to advance, they sink down between the
 mountains which are still before them, where
 they are locked up and squeezed on all sides
 as in a canal. The wind presses these vapours
 from above, and the opposite sides of the two
 mountains confine them on the right and left,
 till, in their progress, they advance to the foot
 of some mountains where the country is more
 flat and open; they then expand, and become
 again invisible. But they are soon pushed
 against another ridge of mountains by fresh

' clouds coming up behind them ; and in this
 ' manner they proceed till they arrive with vast
 ' impetuosity at the top of the highest moun-
 ' tains of the Cape, which are those of the
 ' *Wind* or of the *Table*, where they are met by a
 ' wind blowing in the very opposite direction.
 ' Here a dreadful conflict ensues. The vapours
 ' are pressed both before and behind, which pro-
 ' duces terrible whirlwinds, either on the moun-
 ' tains of the *Table*, or in the valleys. When the
 ' north-west wind yields, that of the south-east
 ' increases, and continues to blow with more or
 ' less violence for six months. When the *Ox's*
 ' *Eye* is thick, the force of the south-east wind
 ' augments, because the vapours amassed behind
 ' the mountains continually press forward ; for
 ' the same reason, this wind diminishes when
 ' the *Ox's Eye* is thin ; and it entirely ceases
 ' when the *Ox's Eye* vanishes, because no va-
 ' pours arrive from the east.

' The circumstances attending this phænomenon lead to the following hypothesis :
 ' 1. Behind the mountain of the *Table*, a train
 ' of thin white vapour is observed, which com-
 ' mences on the eastern declivity of this moun-
 ' tain, ends in a sharp point at the sea, and occu-
 ' pies, in its extent, the whole mountains of
 ' *Stone*. I have often contemplated this train,
 ' and imagined it to originate from the rapid
 ' motion of the vapour above described, from
 ' the mountains of *Stone* to those of the *Table*.

' 2. The .

‘ 2. The passage of these vapours must be extremely embarrassed by the contrary shocks received, not only from the mountains, but from the south and east winds which prevail in the neighbourhood of the Cape. I have already mentioned the two mountains situated on the points of *Falſe Bay*, the one called the *Hanging Lip*, the other the *Norvege*. When the particles or vapours, which I have conjectured, are pushed against these mountains by the east winds, they are repelled by the south winds and driven against the neighbouring mountains, where they are detained for some time, and appear like clouds, as they often do upon the mountains of *Falſe Bay*, and even beyond them. These clouds are frequently very thick above the land in the possession of the Dutch, upon the mountains of *Stellenboſck*, of *Drakenſtein*, and of *Stone*, but especially upon the mountains of the *Table* and of the *Devil*.

‘ Lastly, The constant appearance of small black clouds upon the *Lion’s Head* two or three days before the south-east wind blows, confirms me in my conjecture; for these clouds, in my opinion, are composed of the particles or vapour mentioned above. If the north-west wind prevails when these particles arrive, their course is stopped; but they are never driven to any great distance till the south-east wind commences.

The navigators who first approached the Cape of Good Hope, were ignorant of the effects of these

these clouds, which seemed to arise slowly and without any agitation in the air, but which, in a moment, excite the most furious tempests, and precipitate the largest vessels to the bottom of the ocean. In the country of Natal, a cloud, similar to the Ox's Eye at the Cape, produces the same direful effects. These species of tempests are frequent in the Atlantic, especially in the neighbourhood of the Equator. Near the coast of Guiney, three or four of these storms sometimes happen in a day, which are likewise occasioned and announced by small black clouds, while the rest of the sky is generally serene, and the sea perfectly calm. It is principally in April, May, and June, that these furious storms arise along the coast of Guiney, because no regular winds blow there at that season. On the coast of Loango, the stormy season is in the months of January, February, March, and April. At Cape Gardafu, on the other side of Africa, they have storms of this kind in May, and the clouds which produce them are generally in the north, like those of the Cape of Good Hope.

All these storms originate from winds, which issue from a cloud; and their direction is from north to south, or from north-east to south-west, &c. But there are tempests of another kind, called Whirlwinds, which are still more violent, and in which the wind seems to blow from every quarter at once. Their motion is circular, and nothing can resist their fury. They are generally.

generally preceded by a dead calm ; but, in an instant, the waves are elevated to the clouds by the fury of the winds. Some parts of the sea cannot be approached ; because they are perpetually infested either with calms or whirlwinds. These places have been called *calms* and *tornados* by the Spaniards. The most considerable of them are near Guiney, about the 2d or 3d degree of north latitude. They extend about 300 or 350 leagues in length, and nearly as much in breadth, which includes a space of more than 100,000 square leagues.

When contrary winds arrive at the same time in the same place, they produce whirlwinds, by the opposite motion of the air, in the same manner as whirlpools are produced in the sea by contrary currents. But when these opposite winds are counterbalanced by their distant action upon each other, they then revolve in a great circle, and produce a perfect calm, which it is impossible for vessels to navigate. These places are all marked in the globes of Mr. Senex. I am inclined to think, that the contrariety of winds alone, if not assisted by the direction of the coast, and the particular structure of the bottom of the sea in these places, could not produce this effect. I imagine that the currents, which are in effect occasioned by the winds, but assume their direction from the figure of the coasts and the inequalities at the

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bottom,

bottom, terminate in these places ; and that their opposite motions, in a plain surrounded with a chain of mountains, give rise to the tornados in question.

Whirlpools seem to be nothing else but circular motions of the waters occasioned by the action of two or more opposite currents. The Euripus, so famed by the death of Aristotle, alternately absorbs and rejects the water seven times every 24 hours. This whirlpool is near the coast of Greece. Charybdis, which lies near the straits of Sicily, rejects, and absorbs the water thrice in 24 hours. We are uncertain as to the number of alternate motions in other whirlpools. Dr. Placentia informs us, that the motions of the Euripus are irregular for 18 or 19 days every month, and regular during the other 11 ; and that it seldom swells above one, or at most two feet. He farther informs us, that authors are not agreed as to the tides in the Euripus ; that some say it is twice, others seven times, some 11, others 12 or 14 times in 24 hours ; but that Loirius, who examined it attentively, found that the tides rose regularly every six hours, and that their motion was sufficient to turn a mill-wheel.

The largest known whirlpool is in the sea of Norway, the circumference of which exceeds 20 leagues. It absorbs, for six hours, water, whales, ships, and any thing that approaches it, and

and the next six hours are employed in throwing them up again.

To account for these whirlpools, it is unnecessary to have recourse to an abyfs, or to pits in the bottom of the sea, which are perpetually swallowing the waters. It is well known, that, when water runs in two directions, the combination of these motions produces a whirling, and exhibits the appearance of a void space in the middle. In the same manner, whirlpools in the sea are occasioned by two or more contrary currents, and, as the tides are the principal cause of currents, and, of course, they run for six hours in contrary directions, it is not surprising, that the whirlpools which are produced by them should alternately reject and absorb every thing within their reach during the same portion of time.

Whirlpools, then, are occasioned by contrary currents, and whirlwinds by the conflict of contrary winds. These whirlwinds are common in the Chinese and Japanese seas, near the Antilles, and in many other places of the ocean, particularly in the neighbourhood of prominent coasts. But they are still more frequent upon land; and their effects are sometimes prodigious. ‘I have seen,’ says Bellarmin*, ‘an enormous ditch scooped out by the wind, transported in the air, and dropped upon a village, which was for ever buried under this load of earth.’ A detail of the effects of several hurricanes may be

* De Ascensu Mentis in Deum.

seen in the History of the French Academy, and in the Philosophical Transactions, which would appear altogether inconceivable, if they were not attested by intelligent and credible spectators.

The same observation may be made with regard to water-spouts, which the mariner never beholds without terror and amazement. They are common on certain coasts of the Mediterranean, especially when the weather is cloudy, and the wind blows from several quarters at the same time. They are more frequent near the coasts of Laodicea, of Gręgo, and of Carmel, than in any other part of the Mediterranean. Most of them are large cylinders of water which fall from the clouds, though, at a distance, the water appears to rise up from the sea to the clouds*.

But there are two species of water-spouts; the first is that we have just mentioned, and is nothing but a thick cloud compressed, and surrounded by opposite winds blowing from different quarters at the same time, which make it assume a cylindric figure, and fall down by its own gravity. The quantity of water is so immense, and the rapidity of the fall so great, that if, unfortunately, one of these spouts break upon a ship, it is dashed to pieces, and sinks in an instant. It is alledged, and with probability, that water-spouts may be broken and dissipated by the commotion excited in the air by the

* See Shaw's Travels.

firing of cannons, which corresponds with the dissipation of thunder-clouds by the ringing of bells.

The other species of water-spout is called a *typhon*, and is very frequent in the Chinese Sea. The typhon descends not from the clouds, nor is it produced by the action of opposite winds. On the contrary, it rises from the water to the heavens with amazing rapidity. Whirlwinds often run along considerable tracts, bearing down houses, trees, and every obstacle that they meet with. But typhons remain always in the same places, and can be owing to nothing but subterraneous fires; for the sea is then in the greatest agitation, and the air is so impregnated with sulphureous exhalations, that the sky appears to be covered with a copper-coloured crust, although there be no clouds, and the sun or the stars appear through the vapour. It is to these subterranean fires that we must ascribe the warmth of the Chinese Sea in winter, where these typhons are very frequent*.

Thevenot, in his voyage to the east, gives the following account of water-spouts: ‘ We saw water-spouts in the Persian gulf, between the islands of Quesso, Lareca, and Ormutz. Few have had the opportunity of observing, and fewer still have paid the attention to water-spouts, that I have done. I shall describe them

* See Acta erud. Lips. supplement. tom. i. p. 405.

‘ with perspicuity and simplicity, in order to
 ‘ render my account the more intelligible.

‘ The first that we saw, was on the north side
 ‘ between us and the island of Quesomo, about
 ‘ a gun-shot from our ship. In this place, we
 ‘ saw the water begin to boil, and to be raised
 ‘ about a foot above the surface : It was whitish,
 ‘ and the top of it appeared like black smoke :
 ‘ It made a kind of whispering noise, like a tor-
 ‘ rent rushing down with violence into a deep
 ‘ valley. This noise was mingled with another
 ‘ that resembled the hissing of serpents. A little
 ‘ afterwards, we saw an obscure canal or pipe,
 ‘ which resembled smoke rising to the clouds,
 ‘ and revolved with considerable velocity : This
 ‘ pipe was about the size of a man’s finger ; and
 ‘ the same noise continued. It then vanished,
 ‘ having continued in all about a quarter of an
 ‘ hour. We then perceived another on the
 ‘ south, which began in the same manner as the
 ‘ former : Immediately a third sprung up to the
 ‘ west, and then a fourth likewise to the west ;
 ‘ the most distant from us not exceeding a musket-
 ‘ shot. Each of them appeared like heaps of
 ‘ smoking straw, and were accompanied with
 ‘ the same noise as the first. We next perceiv-
 ‘ ed three pipes, or canals, extending from the
 ‘ water to the clouds, where each of them ter-
 ‘ minated like the mouth of a funnel or trum-
 ‘ pet, or like the paps of an animal drawn per-
 ‘ pendicularly downward by a weight. These
 ‘ pipes.

' pipes were of a dark white colour, which I
 ' imagined to be owing to the water they con-
 ' tained ; for the pipes appeared to be formed
 ' before they were filled with the water, and
 ' they disappeared when they were empty ; in
 ' the same manner as a cylinder of clear glass,
 ' when held up in the light at a distance from
 ' the eye, is not visible, unless it be filled with
 ' some coloured liquor. These pipes were not
 ' straight, but bent in some places : They were
 ' not even perpendicular ; on the contrary, from
 ' the clouds into which they were ingrafted, to
 ' the places from which they extracted the wa-
 ' ter, they were very much inclined. And,
 ' what is singular, the cloud to which the second
 ' of the three was attached, having been pushed
 ' forward by the wind, the pipe followed it
 ' without breaking, or quitting its station in the
 ' water ; and, passing behind the pipe of the first,
 ' they remained for some time in the form of a
 ' St. Andrew's cross. At first, none of the three
 ' exceeded an inch in thickness, except where
 ' they joined the cloud : But the one that ap-
 ' peared first, swelled afterwards considerably.
 ' The other two continued not longer than the
 ' one we had seen to the north. The second,
 ' on the south, lasted about a quarter of an
 ' hour ; but the first, on the same side of the
 ' vessel, continued longer, and gave us some un-
 ' easiness. Concerning it, therefore, we have still
 ' farther to remark, that, although it originally

' was not larger than a man's finger, it gradually
 ' swelled to the size of an arm, then to that of a
 ' leg, and, *lastly*, to that of the trunk of a tree as
 ' large as a man could encompass with both his
 ' arms. We saw the water rising distinctly
 ' through this transparent body, which was of a
 ' serpentine form; and it sometimes diminished in
 ' thickness both above and below. It now ex-
 ' actly resembled a soft tube filled with water,
 ' and pressed with the fingers, either above to
 ' make the fluid descend, or below to make it
 ' ascend; and I was satisfied that these variations
 ' were occasioned by the wind, which, when it
 ' pressed the canal above, caused the water to de-
 ' scend, and when the pressure was lower down
 ' made the water ascend. After this, it dimi-
 ' nished to the size of a man's arm; then it swel-
 ' led to the size of a thigh; then became ex-
 ' ceedingly small; *lastly*, I perceived that the
 ' water elevated from the surface began to sink,
 ' and the end of the canal separated from it;
 ' when a variation of the light removed it from
 ' my view. I still, however, continued to look
 ' for it, because I had remarked, that the canal
 ' of the second spout appeared to break in the
 ' middle, and to reunite a little afterwards, one
 ' half of it having been concealed by the light;
 ' but this last never more appeared.

These spouts are exceedingly dangerous at
 sea; for, when they fall upon a vessel, they
 mingle so with the rain, that they sometimes
 ' raise

' raise the vessel up, and let it fall back again
 ' with such violence as to sink it. But, although
 ' they should not raise the ship, they tear the
 ' sails, or let the whole water they contain fall
 ' upon the vessel, which precipitates it to the
 ' bottom. It is not improbable, that many ves-
 ' sels, of which we never have any accounts,
 ' perish by such accidents, for there are few
 ' examples of our ever learning with certainty
 ' of ships being lost in this manner.'

The above account of water-spouts seems to
 have proceeded from several optical illusions.
 But I have related the facts *verbatim*, that they
 may either be confirmed, or at least compared,
 with those of other navigators. M. Gentil, in his
 voyage round the world, describes water-spouts
 in the following manner : ' At eleven o'clock,
 ' before noon, the sky being cloudy, we saw
 ' around our ship, at the distance of about a quar-
 ' ter of a league, six water-spouts, which began
 ' with a noise like that of water running below
 ' ground, and gradually increased till it resembled
 ' the hissing noise occasioned by a high wind
 ' among the ropes of a ship. We first perceived
 ' that the sea began to boil ; and its surface rose
 ' about a foot and a half ; the top of this ele-
 ' vated part was covered with a thick fog, or
 ' rather smoke, which formed itself into a canal,
 ' and mounted to the clouds. These canals
 ' bended according as the wind carried the
 ' clouds to which they were attached. Not-
 ' withstanding

‘ withstanding the motion communicated to the
 ‘ clouds by the wind, the canals not only ad-
 ‘ hered to them, but seemed to stretch out, or
 ‘ contract, in proportion as the clouds rose high-
 ‘ er, or sunk down in the atmosphere.

‘ These appearances gave us much uneasiness;
 ‘ and our sailors, instead of encouraging each
 ‘ other, increased their fears by dreadful stories.
 ‘ If these spouts, said they, fall upon the ship,
 ‘ they will lift her up, and then plunge her to
 ‘ the bottom. Others maintained, with a deci-
 ‘ sive tone, that they would not lift the vessel;
 ‘ but that, being full of water, if the ship went
 ‘ forward, she would break their communication
 ‘ with the sea, and that the great body of water,
 ‘ by falling perpendicularly on the vessel, would
 ‘ break her in pieces.

‘ To prevent this misfortune, they lowered
 ‘ the sails, and charged the cannon. It is a ge-
 ‘ neral opinion among sailors, that the firing of
 ‘ cannon, by agitating the air, bursts and dis-
 ‘ perses water-spouts. But we were not under
 ‘ the necessity of having recourse to this expedi-
 ‘ ent; for, after coursing round the ship for
 ‘ about ten minutes, some being about a quarter
 ‘ of a league from us, and others nearer, the
 ‘ canals became gradually narrower, detached
 ‘ themselves from the surface of the sea, and then
 ‘ entirely vanished *.

From the description of these two voyagers, it appears, that water-spouts are produced, at least in part, by the action of fire or smoke, which rises with violence from the bottom of the sea; and that they are very different from those which are occasioned by opposite winds: ‘The water-spouts,’ says Mr. Shaw*, which I had the opportunity of seeing, seemed to be so many cylinders of water falling down from the clouds; though, by the reflection, it may be of those descending columns, or from the actual dropping of the water contained in them, they would sometimes appear, especially at a distance, to be sucked up from the sea. Nothing more, perhaps, is required to explain this phenomenon, than that the clouds should be first of all crowded together, and then, that contrary winds, pressing violently upon them, should occasion them to condense, and fall in this cylindrical manner.’

Many facts remain still to be known before these phenomena can be properly explained. To me it appears, that, if there be, in particular places, at the bottom of the sea, a mixture of sulphur, bitumen, and mineral substances, these may occasionally be inflamed, which will produce, like the explosion of gun-powder, a great quantity of air; and that this air newly generated, and rarefied to a prodigious degree, mounts with rapidity, and may elevate the water from

* Shaw's Travels, p. 334.

the sea to the clouds. In the same manner, if a perpendicular current of air be produced by the explosion of sulphureous matter in a cloud, the whole of its water may follow this current, and give rise to a water-spout from the clouds to the sea. But, it must be acknowledged, that this account of the last species of spout is not more satisfactory than that which we have given of those produced by contrary winds; for, it may be asked, why those spouts, which originate from the clouds, are not as common on land as upon the sea?

The historian of the academy for the year 1727, mentions a land water-spout that appeared at Capestan near Beziers. It descended from a cloud like a black pillar, which gradually diminished, and ended in a point upon the surface of the earth. It followed the direction of the wind, which was westerly; it was attended with a thick smoke, and made a noise like the sea when greatly agitated. It tore up trees by the roots, and marked its way on the earth by a large tract in which three carriages might have passed each other. Another pillar of the same kind appeared, but it soon joined the first; and, when the whole was dissipated, there fell a great quantity of hail.

This species of water-spout appears to be different from the other two. It is not said to have contained water; and it seems, both from what I have mentioned, and by M. Andoque's explanation

cation of it to the academy, to have been only a hurricane rendered visible by the dust and condensed vapour which it contained. The same historian, for the year 1741, mentions a waterspout which was seen upon the lake of Geneva. It was of a cylindrical figure, the upper part of which ended in a black cloud, and the under part of it was narrow, and terminated near the surface of the water. This meteor continued only a few minutes; and, at the moment of its dissipation, a thick vapour ascended from the place where it first appeared; the water of the lake boiled, and seemed to make an effort to rise into the air, which was very calm the whole time; neither was this spout followed either by wind or rain. ‘After all our knowledge of waterspouts,’ says the historian, ‘does not this prove that they are not produced by the conflict of opposite winds alone, but that they almost always originate from volcano’s or subterraneous vapours, which are known to exist at the bottom of the sea, as well as upon land? Whirlwinds and hurricanes, therefore, which are generally believed to be the cause of these appearances, may be only an effect or an accidental consequence of them.’

P R O O F S

OF THE

THEORY OF THE EARTH.

A R T I C L E XVI.

Of Volcano's and Earthquakes.

THE bowels of those burning mountains called *Volcano's* contain sulphur, bitumen, and other inflammable materials, the effects of which are more violent than those of thunder or of gun-powder; and they have, in all ages, astonished mankind, and desolated the earth. A volcano is an immense cannon, with an aperture often more than half a league in circumference. From this vast mouth are projected torrents of smoke and of flames, rivers of bitumen, of sulphur, and of melted metals, clouds of ashes and stones; and sometimes it ejects, to the distance of several leagues, rocks so enormous, that they could not be moved by any combination of human

man force. The conflagration is so dreadful, and the quantities of burning, calcined, melted, and vitrified substances thrown out by the mountain, are so great, that they bury whole towns and forests, cover the plains to the thickness of a hundred or two hundred feet, and sometimes form hills and mountains, which are only portions of these matters heaped up and compacted into one mass. The action of the fire and the force of the explosions are so violent, that they produce by reaction, succussions, which shake the earth, agitate the sea, overturn mountains, and destroy towns and buildings of the most solid materials.

These effects, though natural, have been regarded as prodigies; and, though we often behold, in miniature, effects similar to those of volcano's; yet grandeur, from whatever source it proceeds, has such an astonishing influence upon the imagination, that it is not surprising they should have been considered by some authors as vents to a central fire, and, by the vulgar, as mouths of hell. Astonishment produces fear, and fear is the source of superstition. The inhabitants of Iceland believe that the groanings of their volcano are the cries of the damned, and that its eruptions are occasioned by the desperation and ungovernable fury of devils and tormented spirits.

All these phænomena, however, are only the effects of fire and of smoke. In the bowels of mountains,

mountains, there are veins of sulphur, bitumen, and other inflammable substances, together with vast quantities of pyrites, which ferment when exposed to the air or moisture, and produce explosions proportioned to the quantity of inflammable matter. This is the true idea of a volcano; and it is easy for the naturalist to imitate the operation of these subterraneous fires. A mixture of sulphur, of filings of iron, and of water, buried at a certain depth below the ground, will exhibit, in miniature, all the appearances of a volcano: This mixture soon ferments to a degree of inflammation, throws off the earth and stones which cover it, and produces explosions every way similar to those of burning mountains.

The most famous volcano's in Europe are those of Mount *Ætna* in Sicily, of Mount *Hecla* in Iceland, and of Mount *Vesuvius*, near Naples in Italy. The burning of Mount *Ætna* is more ancient than the records of history. Its eruptions are extremely violent; and the quantity of matter it throws out is so enormous, that, after digging 68 feet deep, marble pavements, and other vestiges of an ancient city, have been found covered with this amazing load of ejected matter, in the same manner as the town of *Herculaneum* has been buried with the matter thrown from Mount *Vesuvius*. New mouths, or *aters*, were opened in *Ætna* in the years 1650, 1669, and at other times. The smoke and flames

flames of this volcano are seen as far as Malta, a distance of 60 leagues : It sends forth a perpetual smoke, and, at particular times, it throws out, with astonishing violence, flames, lava, huge stones, and matter of every kind. An eruption of this volcano, in the year 1537, produced an earthquake over the whole island of Sicily, which lasted 12 days, and overthrew an immense number of houses and public buildings. It terminated by the bursting of a new mouth, the lava of which burnt up every thing within five leagues of the mountain. It discharged ashes so abundantly, and with such force, that they reached the coast of Italy, and incommoded vessels at great distances from the island. This volcano has, at present, two principal craters, one of which is narrower than the other. They both smoke perpetually ; but flames only appear during the time of eruptions. Large stones, it is said, have been projected from them to the distance of 60,000 paces.

A violent eruption, in 1683, produced a dreadful earthquake in Sicily. It laid the whole city of Catanea in ruins, and destroyed more than 60,000 of its inhabitants, beside those who perished in the neighbouring towns and villages.

Hecla darts its fires through the snows and ice of a frozen climate. Its eruptions, however, are equally violent with those of *Ætna*, and other volcano's in the more southern regions. It throws out ashes, lava, pumice-stones, and

sometimes boiling water. The whole island of Iceland abounds in sulphur ; but it is not habitable within less than six leagues of the volcano. The history of its most violent eruptions is recorded in a book written by *Dithmar Bleffken*.

According to historians, the burning of Mount Vesuvius began not before the seventh consulate of Titus Vespasian and Flavius Domitian. The top of the mountain then opened, and at first threw out stones and rocks. These were succeeded by flames and lava which burnt up two neighbouring cities, and volumes of smoke so thick as to darken the light of the sun. The elder Pliny, stimulated by curiosity, approached too near the mountain, and was suffocated by its sulphureous steams*. Dion Cassius relates, that this eruption was so violent, that ashes and sulphureous steams were transported as far as Rome, and across the Mediterranean into Africa and Egypt. Heraclea was one of the cities that were overwhelmed by the matter ejected from the mountain : It has lately been discovered 60 feet under the surface of the ground, which, in the course of time, had become arable, and fit for every kind of culture. The history of the discovery of Heraclea is in the hands of the public. We have only to wish, that some person, skilled in the knowledge of nature, would examine with attention the different materials which compose these 60 feet of earth, and remark their

* See Pliny the Younger's Letter to Tacitus.

situation,

situation, the alterations they have undergone, the direction they have followed, the hardness they have acquired, &c.

Naples appears to be situated upon a vault, filled with burning minerals; for Vesuvius and Solfatara seem to have subterraneous communications. When Vesuvius throws out lava, Solfatara emits flames; and, when the eruptions of the former cease, the burning of the latter is likewise extinguished. The city of Naples is nearly in the centre between them.

One of the last and most dreadful eruptions of Vesuvius happened in the year 1737*. The mountain discharged, from several mouths, immense torrents of melted matter, which spread over the fields, and terminated in the sea. M. de Montealegre, who communicated this account of it to the Academy of Sciences, observed, with horror, one of these rivers of fire, which, from its source to the sea, was about 7 miles in length, 50 or 60 paces broad, from 25 to 30 palms deep, and in the valleys 120 palms. The running matter resembled foam, or the dross which issues from a furnace†, &c.

In Asia, and particularly in the islands of the Indian ocean, volcano's are numerous. One of the most famous is Mount Albours, near Mount Taurus, about 8 leagues from Herat. The top

* This volume was published in the year 1749. Several eruptions have happened since that time. See Hamilton's History of Vesuvius.

† See l'Hist. de l'Acad. année, 1737, p. 7.

of this mountain sends forth a perpetual smoke; and it frequently throws out flames and burning matter, in such quantities as to cover all the adjacent plains with ashes. In the island of Ternate, there is a volcano which discharges matter similar to pumice-stones. Some voyagers allege, that this volcano is most furious during the equinoxes, because these periods are attended with certain winds which increase the inflammation of those fires that have continued to burn for ages*. The island of Ternate is not above 7 leagues round, and is only the top of a large mountain. The land rises from the coast to the middle of the island, where the volcano mounts to a height so great, that it is difficult to climb to its top. Several rills of sweet water descend from the sides of the mountain; and, when the air is calm, and the weather fine, this burning gulf is less agitated than during storms and high winds†. This is a confirmation of what I formerly remarked, and seems to prove, that the fire of volcano's proceeds not from a great depth, but from the top or higher parts of the mountain; for, if it were otherwise, high winds could not increase the violence of the flames.

There are other volcano's in the Molucca islands. In one of the islands of Mauritius, about 70 leagues from the Moluccas, there is a volcano, the effects of which are equally violent as those

* See *Voyages d'Argensola*, tom. i. p. 21.

† See *Voyage de Schouten*.

of the mountain at Ternate. The island of Sorca, one of the Moluccas, was formerly inhabited. In the middle of this island there is a very high mountain, with a volcano at its summit. In 1693, this volcano discharged an immense quantity of bitumen, and inflamed matter, which, after forming a burning lake, gradually extended till it covered the whole island*.

There are several volcano's in Japan, and the adjacent islands, which send out flames in the night, and smoke in the day. In the Philippine islands, there are likewise several burning mountains. One of the most remarkable, and, at the same time, the most recent volcano in the Indian islands, is that near the town of Penarucan in the island of Java. It commenced in the year 1586, and, at the first eruption, it threw out immense quantities of sulphur, bitumen, and stones. The same year, Mount Gounapi, in the island of Banda, which had been a volcano about 17 years only, opened and ejected, with a dreadful noise, rocks and matter of every kind. There are still other volcano's in India, as in Sumatra, and in the north of Asia, beyond the river Jenifcea, and the river Pesida: But the two last are little known.

Near Fez in Africa, there is a mountain, or rather a cavern, called *Beni-guazeval*, which constantly throws out smoke, and sometimes flame. One of the Cape de Verd islands, called

* See Phil. Trans. Abridg. vol. ii. p. 391.

the island of *Fuogo*, is nothing but a huge mountain which burns incessantly. This volcano throws out stones and ashes; and the Portuguese, who often attempted to inhabit the island, have always abandoned the project, on account of the volcano. The Peak of Teneriff, which is reckoned one of the highest mountains in the world, throws out fire, ashes, and large stones. From the top of it, rivulets of melted sulphur run down the south side across the snows. This sulphur soon condenses, and forms veins in the snow, which are distinguishable at great distances.

America, and particularly the mountains of Mexico and Peru, are much infested with volcano's: That of Arequipa is one of the most celebrated: It often produces great earthquakes, which are more frequent in Peru than in any country of the world. Next to Arequipa, the volcano's of Carrappa and Malahallo are, according to the relation of travellers, the most considerable. But there are many others in the new world of which we have no knowledge. M. Bouguer, in his voyage to Peru, published in the Memoirs of the Academy for the year 1744, mentions two volcano's, the one called *Cotopaxi*, and the other *Pichincha*. The first is at some distance from, and the other very near, the town of Quito. In the year 1742, he saw an eruption of Cotopaxi, which, at that time, burst open a new mouth in the mountain. It did no other

other damage than that of melting the snow, and producing such torrents, as, in three hours, laid the whole country, to the extent of 18 leagues, under water, and overturned every thing in their course.

Popochampeche and Popocatepec are the chief volcano's in Mexico. It was near this last that Cortes passed in his way to the city of Mexico: Some of the Spaniards ascended to the top of the mountain, where they found the crater to be about half a league in circumference. Sulphureous mountains have also been found in Guadaloupe, Tercera, and in others of the Azore islands; and, if all the mountains from which smoke or flames issue were to be considered as volcano's, their number would exceed 60. We have only mentioned those which are so formidable as, by their frequent eruptions, to prevent people from living near them.

The numerous volcano's in the Cordeliers, as I formerly remarked, produce almost perpetual earthquakes, which prevent the inhabitants from building with stone any higher than the first floor; and the upper parts of their houses, for the same reason, are constructed with rushes or very light wood. In these mountains there are also many precipices and large gulfs, the walls of which are black and burnt: They are similar to the precipice of Mount Ararat in Armenia, called the *Abyss*, and are the craters of extinguished volcano's.

A late earthquake at Lima was attended with the most dreadful effects. The town of Lima, and the port of Callao, were almost entirely swallowed up. But the mischief was still more terrible at Callao. The sea rose and covered every house in that unfortunate town, and drowned the whole inhabitants, leaving only a single tower as a monument of its devastations. Of 25 vessels which lay in the harbour, four were driven a league upon land, and the rest were swallowed up by the waves. Of Lima, which was a very large city, only 27 houses remained standing. Multitudes of people perished; and the disaster was particularly fatal to the monks and other religious, because their buildings were lofty and of more solid materials than the common houses. This calamity happened in the month of October 1746, during the night; and the succession lasted 15 minutes.

Near the port of Pisca, in Peru, there was formerly a famous city, situated on the sea-coast; but, on the 19th of October 1682, it was almost entirely destroyed by an earthquake; for the sea, having exceeded its usual limits, swept away this unfortunate city, with all its inhabitants.

By consulting historians and travellers, we shall find many accounts of earthquakes, and eruptions of volcano's, equally dreadful and destructive as those we have mentioned. Pefidonus,

donius, quoted by Strabo *, relates, that a city of Phœnicia, near Sidon, was swallowed up by an earthquake, with the neighbouring territory, and two thirds of Sidon itself; that this effect was not produced so suddenly as to prevent the inhabitants from escaping by flight; that it extended over most of Syria, and as far as the Cyclades islands and Eubœa, where the fountains of Arethusa suddenly stopped, and appeared a few days afterwards by new sources, at a considerable distance from the old; and that the earthquake continued to shake the island sometimes in one place, and sometimes in another, till the earth opened in the valley of Lepanta, and discharged a great quantity of burning matter. Pliny informs us †, that, in the reign of Tiberius, twelve cities in Asia were overturned; and he mentions ‡, in the following terms, a prodigy occasioned by a violent earthquake. ‘*Factum est semel (quod equidem in*
‘*Ætruscæ disciplinæ voluminibus inveni)* ingens
‘*Ætruræ* portentum, Lucio Marco, Sex. Ju-
‘lio Coss. in agro Mutinensi. Namque mon-
‘tes duo inter se concurrerunt, crepitu maxi-
‘mo adsultantes recedentesque, intor eos flam-
‘ma, fumoque in cœlum exeunte interdium, spec-
‘tante e via Æmilia magna equitum Romano-
‘rum familiarumque et viatorum multitudine.
‘Eo concursu villæ omnes elisæ, animalia per-
‘multa, quæ intra fuerunt, exanimata sunt,’ &c.

* Lib. 1.

† Lib. 1. c. 84.

‡ Lib. 2. c. 83.

St. Augustin tells us*, that, in Lybia, 100 towns were destroyed by an earthquake. In the time of Trajan, the earth opened and devoured the city of Antioch, and a great part of the adjacent country. It was again destroyed by the same cause during the reign of Justinian in the year 528, and 40,000 of its inhabitants perished. It was visited with a third earthquake in the days of St. Gregory, sixty years after the former, which destroyed no less than 60,000 of its inhabitants. In the reign of Saladin, *anno* 1182, most of the cities of Syria and of Judea were laid waste by the same calamity. Earthquakes have been more frequent in Apulia and Calabria than in any other part of Europe. In the time of Pope Pius II. all the churches and palaces of Naples were thrown down, and about 30,000 lives were lost: Those who escaped were obliged to live in tents till houses were built for them. In 1629, 7000 persons perished in Apulia by earthquakes; and, in 1638, the city of Saint Euphemia was swallowed up, and left behind it nothing but a stinking lake: At the same time, Ragusa and Smyrna were almost totally destroyed. In 1692, an earthquake was felt in Britain, Holland, Flanders, Germany, and France: It was most severe along the coasts of the sea, and near great rivers. It agitated at least 2600 square leagues, though it lasted but two minutes. The commotion was greater in

* Lib. 2. de miraculis, c. 3.

the mountains than in the valleys*. On the 10th of July 1688, there was an earthquake at Smyrna, which began with a motion from west to east. The castle was first overturned; its four walls separated from each other, and sunk six feet in the sea. This castle stood formerly on an isthmus, which is now a real island, about 100 paces from the land. The east and west walls fell; but the north and south walls still remain. The city, which is near 10 miles from the castle, was overthrown soon after. The earth opened in many places, attended with subterraneous noises; and five or six dreadful shocks were felt before the approach of night, the last of which lasted about half a minute. The ships in the roads were greatly agitated; the ground on which the town stood sunk two feet; and not above a fourth of the houses withstood the concussion, and those were mostly founded on rock. From fifteen to twenty thousand lives were lost†. In 1695, an earthquake was felt at Bologna in Italy; and it was remarked, as a singular phenomenon, that the sea was much troubled the day preceding‡.

‘ On the 4th of May 1614, a terrible earthquake happened at Tercera, which, beside private houses, overturned eleven churches and nine chapels in the city of Angra; and the city of Praya was so much shaken, that

* See Ray's Discourses, p. 272. † See l'Hist. de l'Acad. des Sciences, année 1688. ‡ Ibid. année 1696.

‘ hardly a house was left standing: And, on
 ‘ the 15th of June 1628, the island of St. Mi-
 ‘ chael was visited with a great earthquake.
 ‘ Near this island, in the open sea, there arose
 ‘ a new island in a place where the water was
 ‘ 150 fathoms deep. This island was more
 ‘ than a league and a half long, and above six
 ‘ fathoms high*.

‘ In the island of St. Michael, another earth-
 ‘ quake began on the 26th of July 1691, and
 ‘ continued to the 12th of the following month.
 ‘ Tercera and Fayal were shaken next day with
 ‘ such violence, that they seemed to turn about.
 ‘ These concussions, however, were repeated
 ‘ there only four times: But, at St. Michael,
 ‘ they ceased not a moment during the space
 ‘ of eleven days. The islanders abandoned their
 ‘ houses, which every where tumbled down be-
 ‘ fore their eyes, and remained the whole time
 ‘ in the open fields, exposed to the injuries of
 ‘ the weather. The whole town of Villa Fran-
 ‘ ca was overturned to the foundation, and most
 ‘ of the inhabitants were buried under its ruins.
 ‘ In several places, the plains were elevated into
 ‘ hills, and, in others, the hills sunk down into
 ‘ valleys. A fountain of fresh water issued from
 ‘ the ground, and run for four days, and then
 ‘ stopped all of a sudden. The air and the sea
 ‘ were in such commotion, that they made a
 ‘ noise resembling the bellowings of ferocious

* See Mandello's Voyages.

‘ animals,

‘ animals. Many people died of fear. There
 ‘ was not a vessel in the harbours which was
 ‘ not agitated in a dangerous manner; and those
 ‘ which lay at anchor, or were under sail, at
 ‘ the distance of twenty leagues, were still more
 ‘ severely tossed. Earthquakes are very fre-
 ‘ quent in the Azores: Twenty years before the
 ‘ period mentioned, a mountain in St. Michael
 ‘ was overturned by a dreadful earthquake*.

‘ In the month of September 1627, an earth-
 ‘ quake levelled one of the two mountains of
 ‘ Manilla, called *Carvalos*, in the province of
 ‘ Cagayon. In 1645, a third part of the city
 ‘ was destroyed by a similar accident, and 300
 ‘ persons perished in the ruins. The following
 ‘ year it was visited by another; and the old
 ‘ Indians tell us, that earthquakes are now less
 ‘ destructive than formerly; but they still build
 ‘ their houses of wood, in which they are imi-
 ‘ tated by the Spaniards.

✓ The number of volcano's in this island con-
 firms the above relation; for, at certain inter-
 vals, they vomit forth flames, shake the earth,
 ‘ and produce all the effects ascribed by Pliny
 ‘ to the eruptions of Vesuvius, such as, chang-
 ‘ ing the beds of rivers, making the neighbour-
 ‘ ing parts of the sea retreat, covering the
 ‘ places adjacent with ashes, projecting stones to
 ‘ great distances, and making reports louder
 ‘ than those of cannons†.’

* Gen. Hist. of Voyages, vol. i. p. 325.
 de Gemelli Careri, p. 129.

† See Voyage

‘ In 1646, an earthquake split a mountain in
 ‘ the island of Machian, and the explosion made
 ‘ a frightful noise. From the cleft issued such
 ‘ a quantity of flames as consumed several plan-
 ‘ tations with their inhabitants. This prodi-
 ‘ gious aperture was to be seen in the year 1685,
 ‘ and it probably remains to this day. It was
 ‘ called the *Wheel-track* of Machian, because it
 ‘ ran from the top to the bottom of the moun-
 ‘ tain, and, at a distance, had the appearance of
 ‘ a high road*.’

The history of the French Academy mentions,
 in the following terms, the earthquakes which
 happened in Italy during the years 1702 and
 1703. ‘ They began in October 1702, and
 ‘ continued till July 1703. The city of Norcia,
 ‘ with its dependencies in the ecclesiastical state,
 ‘ and the province of Abruzzo, suffered most;
 ‘ and the earthquakes were first felt in those
 ‘ places which are situated at the foot of the
 ‘ Appennines, on the south side:

‘ They were frequently accompanied with
 ‘ frightful noises in the air, and these noises
 ‘ were sometimes heard when the earth was at
 ‘ rest, and the sky serene. The most violent
 ‘ concussion was on the 2d of February 1703;
 ‘ and it was attended, especially at Rome, with
 ‘ a remarkable clear sky, and a great calmness
 ‘ in the air.’ At Rome it lasted half a minute,
 and at Aquila, the capital of Abruzzo, three

* See l’Hist. de la Conquête des Moluques, tom. iii. p. 318.

‘ hours..

‘ hours. Beside ravaging the neighbouring country, it destroyed the whole town of Aquila, and buried 5000 persons under its ruins.

‘ The concussions, or vibrations, of the earth, as was discovered by the motion of the lamps in the churches, were nearly from south to north.

‘ The earth opened in two places, and discharged, with violence, great quantities of stones, which covered a whole field, and rendered it barren. After the stones, these apertures threw up water above the elevation of the highest trees. This discharge continued a quarter of an hour, and laid the neighbouring country under water. The water was whitish, like soap-suds, and had no particular taste.

‘ On the top of a mountain near Sigillo, a village about 22 miles from Aquila, there was a considerable plain surrounded with rocks like a wall. The earthquake of the 2d of February converted this plain into a large unequal gulf, its greatest diameter being 25 fathoms, and its least 20. This gulf has been founded with ropes of 300 fathoms, without reaching the bottom. At the time that the gulf was formed, flames were observed to issue out of the mountain, and afterwards a thick smoke, which continued, with some interruptions, for three days.

‘ At

‘ At Genoa they had two slight concussions of the 1st and 2d days of July 1703, the last of which was only felt by the people on the Mole. The sea, at the same time, sunk 6 feet in the port, and continued in this situation a quarter of an hour.

‘ The sulphureous water on the road between Rome and Tivoli sunk two feet and a half, both in the basin and in the canal. The springs and rills of water, which rendered many places of the plain called *Tessine* marshy, were entirely dried up. The depth of the water in the lake called *l'Enfer* was diminished three feet. In place of the old springs, new ones, about a mile distant, appeared : They are probably the same waters, the courses of which have been changed by the concussion of the earth*.’

The same earthquake, which, in 1538, formed the Monti de Cinere near Puzzoli, filled the Lucrin lake with stones, earth, and ashes, and converted it into a marsh†.

‘ Earthquakes, also,’ says Mr. Shaw, ‘ have sometimes been felt at sea. In the year 1724, when I was aboard the *Gazella*, an Algerine cruiser of 50 guns, bound to Bona to relieve the garrison, we felt three prodigious shocks, one after another, as if a weight, at each time, of 20 or 30 ton, had fallen from a great height upon the ballast. This happened when we

* See l’Hist. de l’Acad. des Sciences, année 1704.

† See Ray’s Discourses, p. 12.

‘ were five leagues to the southward of the Seven
 ‘ Capes, and could not reach ground with a line
 ‘ of 200 fathom. The captain told me, that, a
 ‘ few years before, when he was upon a cruise,
 ‘ he felt a much greater one, at the distance of
 ‘ 40 leagues to the westward of the rock of Lif-
 ‘ bon *.’

Schouten, speaking of an earthquake which happened in the Moluccas, says, that the mountains were shaken, and that the vessels at anchor in 30 or 40 fathom water, were shocked, as if they had run ashore, or struck against rocks. ‘ We learn,’ continues he, ‘ from daily experience, that the same happens in the ocean, where no bottom can be found; and that earthquakes agitate vessels, even when the sea is perfectly calm.†.’

Gentil, in his voyage round the world, has the following remarks upon earthquakes: ‘ 1. That, half an hour before the earth begins to shake, all animals appear to be seized with a panic. The horses neigh, break their halters, and run out of the stable; the dogs bark; the birds, as if stupid, fly for shelter into the houses; the rats and mice come out of their holes, &c. 2. That ships at anchor are so violently agitated, that all the parts of which they are composed seem to be torn asunder; their guns break loose, and their masts spring. These facts I should hardly have credited, if

* Shaw's Travels, p. 151. † Voyages, vol. vi. p. 103.

‘ they

' they had not been confirmed to me by the
 ' unanimous testimony of many witnesses. I
 ' know that the bottom of the sea is a continu-
 ' ation of the land; and that agitations of the
 ' one must be communicated to the other; but
 ' I could not comprehend how the different
 ' parts of a vessel, swimming in a fluid, should
 ' be affected in the same manner as if she had
 ' been resting on the ground. Her motion, I
 ' imagined, should have only resembled that
 ' produced by a storm; besides, in the present
 ' instance, the surface of the sea was smooth,
 ' and the whole agitation must have proceeded
 ' from some internal cause, because, at the time
 ' of the earthquake, there was no wind. 3.
 ' That, if the cavern of the earth which con-
 ' tains the subterraneous fire, runs from north to
 ' south, and if the buildings of a town above it
 ' lie in the same direction, the whole houses are
 ' overturned; but, if the vein or cavern runs
 ' across the town, the damage produced by
 ' earthquake is less considerable*.'

When a new volcano breaks out in countries
 subject to earthquakes, they almost entirely cease,
 and are seldom felt, except during great erup-
 tions, as has been observed with regard to the
 island of St. Christophers†.

The enormous ravages produced by earth-
 quakes have induced some naturalists to imagine,

* See Voyage de M. le Gentil, tom. i. p. 172.

† See Phil. Trans. abridg. vol. ii. p. 392.

that mountains, and all the other irregularities on the surface of the globe, have derived their origin from succussions of the earth occasioned by the action of subterraneous fires. This, for instance, is the opinion of Mr. Ray. He believes that all the mountains have been formed by earthquakes, or by the explosions of volcano's, in the same manner as Monti de Cinere in Italy, the new island near Santorini, &c. But he has not considered, that the small elevations formed by earthquakes, or by the eruptions of volcano's, are not, like all other mountains, composed of horizontal strata; for, by digging into the Monti de Cinere, we find calcined stones, ashes, burnt earth, iron-drofs, pumice-stones, all blended together like a heap of rubbish. Besides, if earthquakes and subterraneous fires had raised the great mountains of the earth, as the Cordeliers, Mount Taurus, the Alps, &c. the prodigious force requisite to elevate these enormous masses would, at the same time, have destroyed a great part of the surface of the globe. Earthquakes sufficient to produce such effects must have been inconceivably violent, since the greatest of them recorded in history have not been able to produce a single mountain. In the reign of Valentinian I. for instance, an earthquake was felt over the whole known world*, and yet it raised not a single mountain.

It is capable of demonstration, however, that though an earthquake should have a force sufficient to raise the highest mountains, this force would not be able to displace the rest of the globe.

For, let it be supposed, that the chain of high mountains which traverse South America from the point of Terra Magellanica to New Granada and the Gulf of Darien, had been suddenly elevated by an earthquake, and then let us estimate the effect of this explosion. This chain of mountains is about 1700 leagues long, and, at a medium, 40 leagues broad, including the Sierras, which are lower than the Andes. This gives a surface of 68,000 square leagues. The thickness of the matter displaced by the earthquake I suppose to be one league; or, that the mean height of the mountains from their summits to the caverns, which, agreeable to this hypothesis, must support them, is one league. The force of the explosion, therefore, must have elevated, to the height of a league, a quantity of earth equal to 68,000 cubic leagues. But, action and reaction being equal, this explosion must have communicated an equal quantity of motion to the whole globe. Now, the whole globe consists of 12,310,523,801 cubic leagues. From this number take 68,000, and there remains 12,310,455,801 cubic leagues, of which the quantity of motion would be equal to that of 68,000 elevated one league. Hence it appears, that

that the force necessary to raise 68,000 cubic leagues would not be sufficient to displace the whole globe a single inch.

There is no absolute impossibility, therefore, in the supposition, that the mountains have been raised by earthquakes, were it not evident, both from their internal structure and their external figure, that they have been formed by the operation of the waters of the ocean. Their interior parts are composed of parallel strata, interspersed with sea-shells; and their external figure consists of angles every where corresponding. Is it credible that this uniform structure, and regular figure, could have been produced by sudden and desultory succussions of the earth?

But, as this notion has been embraced by some philosophers, and, as the nature and effects of earthquakes are not well understood, I shall hazard a few ideas, which may, perhaps, throw some light upon this intricate subject.

The surface of the earth has undergone many changes. At considerable depths, we find holes, caverns, subterraneous rivulets, and voids, which sometimes communicate with each other by means of chinks and fissures. There are two species of caverns: The first are those which have been formed by volcano's and the action of subterraneous fires. The action of subterraneous fire elevates, shakes, and throws off to a distance the superincumbent materials; at the same time, it splits and deranges those on each

3

side

side of it, and thus produces caverns, grottos, and irregular hollows. But such effects are only exhibited in the neighbourhood of volcano's, and are not so frequent as the other species of caverns which are produced by the operation of water. It has already been remarked, that the different strata of the earth are all interrupted by perpendicular fissures, the origin of which shall be afterwards explained. The waters which fall upon the surface descend through those fissures, collect when their progress is prevented by a stratum of clay, and form springs and rivulets. From the nature of water, it searches for cavities or small vacuities, and has a constant tendency to force a passage, till it finds a proper vent. Wherever it goes, it carries along with it sand, gravel, and other bodies which it is capable of dividing or dissolving. In this manner, the operation of water proceeds till it forms subterraneous passages; and then it breaks out in the form of fountains, either on the surface of the earth, or in the bottom of the sea. The materials it perpetually carries off leave hollows or caverns in the bowels of the earth, which are often of great extent; and these caverns have a very different origin from those produced by volcano's or earthquakes.

Earthquakes are of two kinds: Those occasioned by the action of subterraneous fires, and by the explosions of volcano's, are only felt at small distances, previous to, or during the time

time of eruptions. When the inflammable matters in the bowels of the earth begin to ferment and to burn, the fire makes an effort to escape in every direction; and if it finds no natural vents, it forces a passage, by elevating and throwing off the incumbent earth. In this manner volcano's commence, and their effects continue in proportion to the quantity of inflammable matter they contain. When the quantity of inflamed matter is inconsiderable, it produces only an earthquake, and exhibits no marks of a volcano: The air generated by subterraneous fire may also escape through small fissures; and, in this case, likewise, it will be attended with a succussion of the earth; but no volcano will appear.

But when the quantity of inflamed matter is great, and when it is confined on all sides by solid and compact bodies, an earthquake and a volcano are the necessary consequences. All these commotions, however, constitute only the first species of earthquakes, which are not felt but in the neighbourhood of the places where they happen. A violent eruption of *Ætna*, for example, will shake all the island of Sicily; but it will never extend to the distance of three or four hundred leagues. When *Vesuvius* bursts open a new mouth, it excites an earthquake in Naples and in the neighbourhood of the volcano; but these earthquakes never shake the Alps, nor do they extend to France or other countries distant from *Vesuvius*. Thus, earthquakes produced

by volcano's are limited to a small space ; they are nothing but effects of the reaction of the fire, and they shake the earth in the same manner as the explosion of a powder-magazine occasions an agitation to the distance of several leagues.

But there is another species of earthquakes, which are very different in their effects, and perhaps also in their cause. These earthquakes are felt at great distances, and shake a long tract of ground without the intervention either of a new volcano, or of eruptions in those which already exist. There are instances of earthquakes which have been felt at the same time in Britain, in France, in Germany, and in Hungary. These earthquakes always extend more in length than in breadth. They shake a zone or belt of earth with greater or less violence in different places, and they are generally accompanied with a hollow noise, like that of a heavy carriage rolling with rapidity.

As to the causes of this species of earthquake, it must be remarked, that the explosion of all inflammable substances, like that of gun-powder, generates a great quantity of air ; that this air is highly rarefied by heat ; and that its effects, from the compression it receives by being confined in the bowels of the earth, must be exceedingly violent. Let us suppose, that, at the depth of 100 or 200 fathoms, there are a vast collection of pyrites and sulphureous bodies, and that they are inflamed by the fermentation produced

duced by the admission of water to them, or by other causes. What must be the effect? In the first place, these substances are not placed in horizontal beds, like the ancient strata, which were formed by the sediments of the waters. They are lodged, on the contrary, in the perpendicular fissures, in subterraneous caverns, and other places, to which the water has access. When inflamed, they generate a vast quantity of air, the spring of which, by being compressed within a small space, like that of a cavern, will not shake the earth immediately above, but it will search for passages in order to expand and make its escape. Caverns and channels of subterraneous rivulets and springs, are the only natural passages for this rarefied air. Into these, therefore, it will rush with impetuosity, and produce in them a furious wind, the noise of which will be heard on the surface; and it will be attended with vibrations or succussions of the ground. This subterraneous wind produced by fire will extend the whole length of the caverns or channels, and occasion a shaking, more or less violent, in proportion to its distance from the heat, and to the width or narrowness of the canals. But this motion must necessarily run in a longitudinal direction; and the shaking, of course, must be felt over a long belt of ground. This air, however, cannot produce an eruption or a volcano, because it finds sufficient room for expanding itself, and diminishing its force; or, rather, because it escapes through fissures in

the form of vapour or of wind. But, although the existence of caverns or channels for the passage of this rarefied air should be denied, it is easy to conceive, that in the very place where the explosion is made, as the earth is elevated to a considerable height, the neighbouring places must split horizontally in attempting to yield to the impulse communicated by the original motion; and, in this manner, passages may be gradually and successively opened, so as to communicate with very distant places. This explication corresponds with all the phænomena. Earthquakes are not felt at great distances at the same minute, or even the same hour. They are not accompanied with eruptions or external fire; and the noise almost constantly marks the progressive motion of the subterraneous wind. Other facts concur in establishing this theory. Blasts of wind, and vapours, sometimes of a suffocating nature, it is well known arise from mines, independent of the motion of the air produced by the current of water. It is equally well known, that winds issue from certain apertures of the earth, from caverns, abysses, and deep lakes, as Lake Boleslaw in Bohemia, which has been formerly mentioned.

When these remarks are considered, I cannot comprehend how the mountains should have originated from earthquakes, since the mineral and sulphureous bodies which occasion them are seldom to be met with but in the perpendicu-

lar

lar fissures of mountains, and in other cavities of the earth, the greatest number of which have been produced by the operation of water ; since these inflammable substances produce only a momentary explosion, and violent winds which follow the channels of subterraneous waters ; since the duration of earthquakes on the surface of the earth is so short, they must be occasioned by a sudden explosion, and not by a continued conflagration ; and, *lastly*, since those earthquakes, which extend over large tracts of ground, never produce the smallest eminence throughout their whole course.

Earthquakes, it is true, are more frequent in the neighbourhood of volcano's, as in Sicily, and the environs of Vesuvius : But it appears, from repeated observations, that these earthquakes are very limited, and, consequently, can never form a chain of mountains.

It has sometimes been remarked, that the matters ejected from *Ætna*, after cooling for several years, and being afterwards moistened with rain, have rekindled, and thrown out flames with such violent explosions, as to occasion small earthquakes.

In 1669, during a violent eruption of *Ætna*, which began on the 11th of March, the summit of the mountain sunk considerably* ; which is a proof that this volcano proceeds rather from the superior part of the mountain than from

* See *Phil. Trans. Abridg.* vol. ii. p. 387.

the bottom of it. Borelli, who is of the same opinion, observes, 'That the fire of a volcano proceeds
' neither from the centre, nor from the bottom of
' a mountain, but from the top; and that the in-
' flammation never kindles but at a small depth*.'

Mount Vesuvius has frequently thrown out, during eruptions, great quantities of boiling water. Mr. Ray, who imagines that the fire of volcano's comes from a very great depth, says, that this water proceeds from the sea, which communicates, by subterraneous passages, with the foot of the mountain. As a proof, he mentions the remarkable dryness of the top of Vesuvius, and the agitation of the sea during eruptions, which sometimes recedes so far as to leave the port of Naples entirely dry. But, supposing these facts to be true, they by no means prove that the fire of volcano's proceeds from a great depth; for the water they eject is certainly rain-water, which penetrates through the fissures, and collects in the cavities of the mountain. Rills, and springs issue from the tops of volcano's, as well as from other high mountains; and, as the former are hollow, and have suffered more concussions than the latter, nothing can be more natural than they should collect water in their caverns, and that these waters should sometimes be ejected, along with other substances, in the time of eruptions. With regard to the motion of the sea, it arises solely from the shock com-

* Borelli de incendiis Montis Ætnæ.

communicated

municated to the waters by the explosion, which makes them advance or retire according to different circumstances.

The most common substances thrown out by volcano's, are torrents of melted minerals, which overflow the environs of the mountain. These rivers of lava extend to great distances; and, in cooling, they form beds, either horizontal or inclined, in the same manner as the strata accumulated by successive sediments from water. But the former are easily distinguishable from the latter: 1. Because strata of lava are not every where equal in thickness. 2. Because they contain nothing that has not evidently been calcined, vitrified, or melted. 3. Because their extent is more limited. As there is a vast number of volcano's in Peru, and as the bottoms of most of the Cordeliers are covered with substances which have been thrown out by eruptions, it is not surprising that no sea-shells have been found there; for they must have been calcined and destroyed by the fire. But I am still persuaded, that, if the clay ground, which, according to M. Bourguet, is the ordinary earth in the valley of Quito, had been dug, shells would have been discovered there, as well as every where else, especially where the ground is not covered, like the bottoms of the mountains, with matters ejected from volcano's.

It has often been asked, Why all volcano's appear in high mountains only? I have partly

solved this question in the preceding article. But, before finishing the present subject, I shall endeavour more fully to explain myself.

The peaks or points of mountains were originally covered with earth and sand, which, after being gradually washed down to the valleys by the rains, left nothing but those bare rocks or stones called the core of mountains, which, being likewise subjected to the action of the weather, small and large fragments of them must have been occasionally loosened, and, of course, must have rolled down to the plains. The rocks at the base of the summit being fully uncovered, and having lost their original support from the sand and earth, would necessarily give way a little, and, by separating from each other, would produce small intervals. But this yielding of the lower rocks could not take place without rending those which lay above them. In this manner the core of the mountain, from the summit to the base of the lower rocks, would be split into an infinite number of perpendicular fissures of different dimensions. Through these the rains would penetrate, and carry along with them, into the bowels of the mountain, all the minerals, and other substances which they were capable of transporting or dissolving. Here pyrites, sulphur, and other combustible substances, would be produced; and, in the course of time, these bodies would accumulate in great quantities, and, by their fermentation, would give rise to explo-

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sions and other effects of volcano's. Hcaps of these mineral substances might likewise exist in the heart of the mountain, before the rain could penetrate so deep. In this case, as soon as the air or rain got access to them by means of the perpendicular fissures, a conflagration and volcano would instantly take place. No such phænomena can be exhibited in plains; for, as every thing there is at rest, and nothing can be displaced, it is not surprising that the existence of volcano's should be confined entirely to the mountains.

When coal-mines are opened, which are commonly found in clay-grounds, and at a great depth, the mineral substances above mentioned sometimes kindle into flames. There are examples in Scotland, Flanders, &c. of coal-mines which have continued to burn for many years. The admission of air is alone sufficient to produce this effect. But these inflammations occasion only slight explosions, and never form volcano's; because, in such places, all being plain and solid, the fire cannot be excited to such a degree as in burning mountains, which are full of caverns and cliffs through which the air penetrates, and augments the action of the fire so forcibly, as to give rise to the terrible effects we have been describing.

P R O O F S

OF THE

THEORY OF THE EARTH.

A R T I C L E XVII.

*Of New Islands, Caverns, perpendicular Fissures,
&c.*

NEW islands are produced either suddenly by the operation of subterraneous fires, or slowly by the accumulated sediments of water. Upon this subject we are furnished with indubitable facts, both by ancient historians, and by modern voyagers. Seneca tells us, that, in his time, the island of Therasia * suddenly emerged from the sea, to the astonishment of many spectators. Pliny relates, that 13 islands formerly arose all at once from the bottom of the Mediterranean, and that Rhodes and Delos are the chief of them. According to Ammianus Marcellinus, Philo, Pliny, &c. these 13 islands were

* Now called Santorini.

not formed by an earthquake or by a subterraneous explosion, but were formerly concealed under the water, which sunk and uncovered them. Delos was even distinguished by the name of Pelagia, because it formerly belonged to the sea. Whether these 13 new islands were produced by the action of subterraneous fire, or by any other cause which diminished the quantity of water in the Mediterranean, it is not easy to determine. But we are informed by Pliny himself, that the island of Hiera, in the neighbourhood of Therasia, is composed of ferruginous masses, and of earth which had been thrown up from the bottom of the sea; and, in another place, he mentions several other islands which had been formed in the same manner. Upon this subject, however, we have facts more recent, and less involved in obscurity.

On the 23d day of May 1707, at sun-rising, there appeared, at the distance of two or three miles from the island of Therasia or Santorini, something which had the resemblance of a floating rock. Some men, stimulated by curiosity, approached it, and discovered that it had arisen from the bottom of the sea; that it increased under their feet; that oysters and other shells still adhered to the rocks; and that many pumice-stones lay on its surface. Two days before this rock appeared, there had been a slight earthquake

Santorini. This island continued to augment considerably, without any accident, till the 14th of

of June. It was then about half a mile in circumference, and 20 or 30 feet high, and the earth was white and mixed with clay. After this time, the sea began to be more and more agitated; vapours arose from it which infested the island of Santorini, and on the 16th of July, 17 or 18 rocks rose all at once from the bottom of the sea, and united into one mass. These phænomena were attended with a frightful noise, which continued two months; and flames issued from the new island, which still augmented both in circumference and height; and the explosions were so violent, that they drove large stones to more than 7 miles distance. The island of Santorini itself was regarded by the ancients as a recent production; and, in 726, 1427, and 1573, it received considerable additions, beside the small islands formed in its neighbourhood*. The same volcano, which, in the days of Seneca, raised the island of Santorini, produced, in Pliny's time, that of Hieræ or Volcanella, and, in our days, the rock above described.

On the 10th of October 1720, a great fire was seen to arise from the sea near the island of Tercera. Navigators being sent, by order of government, to examine it, they perceived, on the 19th of the same month, an island covered with fire and smoke; and a prodigious quantity of ashes was thrown to a great distance, as from a volcano, and accompanied with a noise similar to that

* See l'Hist. de l'Acad. des Sciences, 1708, p. 23.

of thunder. The earth was also perceived to shake in the neighbourhood; and a vast number of pumice-stones were found floating on the sea all round the new island: This last phenomenon has sometimes been remarked in the open sea*.

The historian of the French academy†, in relating this event, remarks, that, after an earthquake in the island of St. Michael, one of the Azores, there appeared a torrent of fire between this island and that of Tercera, which gave rise to two new rocks: And, in the subsequent year, the same historian gives the following detail:

‘ M. de l’Isle has informed the academy of several particulars concerning the new island among the Azores, which he received in a letter from M. de Montagnac consul at Lisbon. On the 18th of September 1721, M. de Montagnac’s vessel was moored off the fortress of St. Michael; and he learned the following particulars from the pilot of the port. ’

‘ During the night of the 7th or 8th of December 1720, there was a great earthquake in Tercera and St. Michael, which islands are distant from each other about 28 leagues, and a new island rose from the sea. It was, at the same time, remarked, that the point of the island of Peak, at the distance of 30 leagues,

* See Philosophical Transact. Abridg. vol. vi. part 2. p. 154.
† Ann. 1721, p. 26.

‘ which

' which formerly threw out flames, was extin-
 ' guished. But a continual thick smoke issued
 ' from the new island, which was distinctly per-
 ' ceived by M. de Montagnac, as long as he
 ' continued in that part. The pilot assured him,
 ' that he had sailed round the island, and ap-
 ' proached it as near as he could with safety.
 ' He founded on the south side of it with a rope
 ' of 60 fathoms; but found no bottom. On the
 ' west side, the water was much changed: It ap-
 ' peared to be mixed with white, blue, and
 ' green; and, at the distance of two miles, it
 ' seemed to be shallow and boiling. On the
 ' north-west, the side from which the smoke
 ' issued, he found, at 15 fathoms, a bottom of
 ' coarse sand. He threw a stone into the sea,
 ' and, at the place where it fell, he observed the
 ' water boil, and mount into the air with great
 ' impetuosity. The bottom was so hot, that, at
 ' two different times, it melted a piece of suet
 ' which had been fastened to the end of the
 ' plumb-line. The pilot likewise remarked,
 ' that smoke issued from a small lake, in the
 ' midst of a sandy plain. This island is nearly
 ' round, and high enough to be perceived, in
 ' clear weather, at the distance of seven or eight
 ' leagues.

' We have since learned, by a letter from M.
 ' Adrien, French consul at St. Michael, dated
 ' in March 1722, that the new island is consi-
 ' derably diminished; that it is nearly on a
 ' level

‘ level with the water; and that it will probably soon disappear.’

From these, and many other facts of a similar nature, it is apparent, that inflammable bodies exist under the bottom of the sea, and that they sometimes produce violent explosions. The places where they happen may be considered as submarine volcano’s, which differ from common volcano’s only in the shorter duration of their effects; for, after the fire opens a passage to itself, the water rushes in, and extinguishes them. The elevation of new islands necessarily leaves caverns, which are soon filled by the waters; and the new ground, which consists of matter thrown out by the submarine volcano, must, in every respect, resemble that of the Monti di Cinere, and other eminences which have been raised by terrestrial volcano’s. It is on account of the waters rushing into the voids and fissures produced by explosions, that submarine volcano’s exhibit their effects less frequently than common volcano’s, though both derive their origin from the same cause.

To subterraneous, or rather submarine, fires, must be ascribed all those ebullitions of the sea, and water-spouts, which have been remarked in different places by mariners: They also produce storms and earthquakes, the effects of which are felt equally at sea as upon land. The islands raised by submarine volcano’s are generally composed of pumice-stones and calcined rocks.

Fire

Fire has frequently been observed to issue out of the waters of the sea. Pliny tells us, that the whole surface of the Thrasymen lake has appeared to be inflamed; and Agricola informs us, that, when a stone was thrown into the lake of Denstat in Thuringia, its descent was marked by a train of fire.

Lastly, The great quantities of pumice-stones discovered by voyagers in different parts of the ocean, as well as in the Mediterranean, evince the existence of volcano's in the bottom of the sea, which differ not from those upon land, either in the violence of their explosions, or in the matter they throw out, but only in their rarity, and in the shortness of their duration. Hence it may be remarked, that the bottom of the sea every way resembles the surface of the earth, not admitting even the exception of volcano's.

Between sea and land volcano's there are many relations. Both of them exist on the tops of mountains. The Azore islands, and those of the Archipelago, are only the points of mountains, some of which are above, and others under, the surface of the water. From the account of the new islands among the Azores, it appears, that the place where the smoke issued was only 15 fathoms deep, which, when compared with the ordinary depth of the ocean, demonstrates this place to be the top of a pretty high mountain. The same remark may be
made

made with regard to the new island near Santorini. Its depth must have been inconsiderable, since oysters were found attached to the rocks which rose above the surface of the water. It likewise appears, that sea-volcano's, as well as those upon land, have subterraneous communications; for, at the very time that the new island among the Azores arose, the summit of the volcano of St. George, in the island of Peak, sunk. It also merits observation, that new islands never appear but in the neighbourhood of old ones; and that there are no examples of new islands in open seas: They ought, therefore, to be regarded as continuations of the ancient islands; and, when volcano's happen to exist in the latter, it is not surprising that the former should contain the same materials, which may be kindled either by fermentation alone, or by the action of subterraneous winds.

Besides, new islands produced by earthquakes, or by subterraneous fires, are few in number. But the number of those formed by slime, sand, and earth, transported by rivers, or by the motions of the sea, is almost infinite. At the mouths of rivers, such quantities of earth and sand are amassed, as frequently give rise to islands of considerable extent. The sea, by retiring from certain coasts, leaves uncovered the highest parts of the bottom, and these parts constitute so many new islands. In the same manner, when the sea encroaches upon the land, it

covers the plains, and the more elevated grounds appear in the form of islands. It is for this reason that there are few islands in the open seas, and that they are so numerous near the coasts.

Fire and water, though of very opposite natures, exhibit many effects so similar, that the one may often be mistaken for the other. Beside the productions peculiar to these elements, as crystal, glass, &c. they give rise to many great phenomena, which have such strong resemblances, that they can hardly be distinguished. Water, as we have seen, elevates mountains, and forms the greatest number of islands: Some mountains and islands likewise derive their origin from fire. The same observation is applicable to caverns, fissures, gulfs, &c. Some of them are the effects of fire, and others of water.

Caverns are, in a great measure, peculiar to mountains: They are seldom or never found in plains. They are frequent in the Archipelago, and other islands; because islands are generally nothing but the tops of mountains. Caverns, like precipices, are formed by the sinking or mouldering of rocks, or, like abysses, by the action of fire; for, to make a cavern form a precipice or an abyss, nothing farther is necessary than that the tops of the opposite rocks should come together and form an arch, which must frequently happen when they are loosened at the root, and shaken by earthquakes, or by the operation of time and of the weather. Ca-

verns may be produced by the same causes which give rise to gulfs, apertures, or sinkings of the earth; and these causes are explosions of volcano's, the action of subterraneous vapours, and earthquakes, which create such commotions in the earth, as must necessarily produce caverns, fissures, and hollows of every kind.

The cavern of St. Patrick in Ireland is not so considerable as it is famous: The same remark may be made with regard to the Grotto del Cane in Italy, and to that of Mount Beni-guazeval, in the kingdom of Fez, which throws out fire. There is a very large cavern in the county of Derby in England. It is much larger than the celebrated cavern of Bauman, near the Black Forest of Brunswick. I was informed by the Earl of Morton, a philosopher more respectable for his merit than his high rank, that the entrance to this cavern, called the *Devil's-hole*, is larger than the door of any church; that a small river runs through it; that, after advancing some way, the vault of the cavern sinks down so low, that, in order to proceed farther, it is necessary to lie flat in a boat, and to be pushed through this narrow passage by people accustomed to the business; and that, after getting through, the roof, or arch of the cavern, rises to a great height; and, after walking a considerable way on the side of the river, the arch sinks again so low as to touch the surface of the water. Here the cavern terminates. The river,

which seems to have its source in this part of the cavern, swells occasionally, and transports heaps of sand, which, by accumulating, forms a kind of blind alley, whose direction is different from that of the principal cavern.

In Carniola, near Potpechio, there is a large cavern, in which is a pretty considerable lake. Near Adelsperg, we meet with a cavern in which a man may travel two German miles. It contains several tremendous and deep precipices*. The Mendip hills in Somersetshire likewise present us with extensive caverns, and very fine grottos. Near these caverns we find veins of lead, and sometimes large oak-trees, buried 15 fathoms deep. In the county of Gloucester, there is a large cavern called *Pen-park-hole*, at the bottom of which we meet with 32 fathoms of water. Here are also veins of lead.

It is apparent, that the Devil's-hole, and other caverns, from which large springs or brooks issue, have been gradually formed by the operation of the water, and their origin cannot be ascribed to earthquakes or volcano's.

One of the largest and most singular caverns we are acquainted with, is that of Antiparos, of which M. Tournefort has given a complete description. We first find a rustic cave about 30 feet wide, divided by some natural pillars. Between two pillars on the right, the ground slopes gently, and then more precipitately for about

* See *Acta erud.* Lips. anno 1689, p. 558.

20 paces to the bottom of the cavern. This is the passage to the grotto or interior cave, and is nothing but a dark hole, through which a man cannot pass without stooping, and the assistance of lights. We then descend, by means of a rope fixed at the entrance, a horrible precipice, and arrive on the borders of another still more tremendous, with corresponding abysses on the left. By a ladder placed on the margin of these gulfs, we get over a vast perpendicular rock. We then continue to slip through places less dangerous. But, when we think ourselves in the greatest safety, we are suddenly stopped by a frightful pass; to escape through which, we are obliged to glide on our backs along a large rock, and to descend by means of a ladder. When we arrive at the bottom of the ladder, we stumble for some time among irregular rocks, and then the famous grotto presents itself. This grotto is about 300 fathoms below the surface of the earth, and it appears to be about 40 fathoms high, and 50 wide. It is full of large and beautiful stalactites, which both depend from the roof of the vault and cover the floor*.

In that part of Greece called Achaia by the ancients, now Livadia, there is a large cavern in a mountain which was formerly famous for the oracles of Trophonius: It is situated between the Lake of Livadia and the sea, from which, at the nearest part, it is distant about four miles; and

* See Tournefort's voyage to the Levant.

there are no less than 40 subterraneous passages through which the waters run under the mountain*.

In all countries which are subject to earthquakes or volcano's, caverns are frequent. The structure of most of the islands of the Archipelago is exceedingly cavernous. The islands in the Indian Ocean, and particularly the Moluccas, appear to be chiefly supported upon vaults. The land of the Azores, of the Canaries, of the Cape de Verd islands, and, in general, of almost all small islands, is, in many places, hollow and full of caverns; because these islands, as formerly remarked, are only the tops of mountains, which have suffered great convulsions either from volcano's, or by the action of the waters, of frosts, and of other injuries of the weather. In the Cordelieres, where volcano's and earthquakes are frequent, there are many caverns, precipices, and abysses.

The famous labyrinth in the island of Crete, is not the work of nature alone. We are assured by M. Tournefort, that, in many parts of it, the operation of men is evident; and, it is probable, that this is not the only cavern which has been augmented by art. Mines and quarries are constantly digging; and, after these have been long deserted, it is not easy to determine whether such excavations have been the effects of nature or of art. Some quarries are amazingly exten-

* See Gordon's Geography, p. 179.

five. That of Maestricht, for instance, is sufficient to shelter 50,000 men, and is supported by more than 1000 pillars of 20 feet high; and the earth and rock above is 25 fathoms thick*. The salt mines of Poland exhibit excavations still more extensive. Near large cities, quarries and artificial hollows are common. But we must proceed no farther in detail. Besides, the operations of men, however great, will always make but an inconsiderable figure in the history of nature.

Volcano's and water, which form caverns in the bowels of the earth, produce likewise on its surface fissures, precipices, and abysses. At Cajeta in Italy, there is a mountain which had been formerly split by an earthquake in such a manner, that the separation seems to have been made by the hands of men. We have already mentioned the *Wheel-track*, or great fissure in the island of Machian, the abyss of Mount Ararat, the port or gap in the Cordelieres, that of Thermopylæ, &c. To these we might add the gap in the mountain of the Troglodites in Arabia, and that of the *Ladders* in Savoy, which was begun by nature, and finished by Victor-Amadæus. Considerable sinkings in the earth, the fall of rocks, and the subversion of mountains, are frequently produced by the waters, as well as by subterraneous fires. Of this many examples might be given.

* See Phil. Transf. Abridg. vol. ii. p. 463,

‘ In the month of June 1714, a part of the
 ‘ mountain of Diableret in Valois fell sudden-
 ‘ ly, and, in a few hours, the sky being serene,
 ‘ it appeared to have assumed a conical figure.
 ‘ It destroyed 55 houses, besides several men, and
 ‘ a great many cattle; and it covered a league
 ‘ square with its ruins. The sky was darkened
 ‘ with the dust: The collection of stones and
 ‘ earth which were amassed on the plain, exceed-
 ‘ ed 30 Rhenish perches in height, dammed up
 ‘ the waters, and gave rise to new lakes of con-
 ‘ siderable depths. But this phenomenon was
 ‘ not accompanied with the least vestige of bitu-
 ‘ men, sulphur, or calcined lime-stone; nor, con-
 ‘ sequently, of subterraneous fire: The base of
 ‘ this great rock appeared to be rotten, and re-
 ‘ duced to powder*.’

There is a remarkable example of these sink-
 ings near Folkestone in the county of Kent. The
 hills in the neighbourhood sunk insensibly, with-
 out any earthquake or other commotion. The
 interior parts of these hills consist of rocks and
 chalk; and, by their sinking, they have pushed
 part of the adjacent land into the sea. A well
 attested relation of this fact may be seen in the
 Philosophical Transactions†.

In 1618, the town of Pleurs was buried un-
 der the rocks at the foot of which it had been
 situated. In 1678, a great inundation was oc-

* Hist. de l'Acad. des Sciences, année 1715, p. 4.

† Abridg. vol. iv. p. 250.

caſioned, in Gaſcony, by the ſinking of ſome portions of one of the Pyrennees, which forced out the water that had been pent up in the ſubterraneous caverns of theſe mountains. In the year 1680, a ſtill greater inundation was produced in Ireland, by the ſinking of a mountain into caverns which had been full of water. It is not difficult to inveſtigate the cauſe of theſe effects. It is well known, that ſubterraneous waters are every where frequent. Theſe waters gradually work away ſand and earth in their paſſages; and, conſequently, they may, in the courſe of time, deſtroy the ſtratum of earth which ſerves as a baſis to the mountain: If this ſtratum fail more on one ſide than on another, the mountain muſt, of neceſſity, be overturned; or, if the baſe waſtes gradually and equally throughout, the mountain will ſink, without being overturned.

Having mentioned a few of thoſe convulſions and changes produced in the earth by what may be called the accidents of nature, we muſt not paſs over in ſilence the perpendicular fiſſures in the different ſtrata. Theſe fiſſures are obvious, not only in all rocks and quarries, but in clays, and in every ſpecies of earth which has never been removed from its natural poſition. They are called perpendicular fiſſures; becauſe, like the horizontal ſtrata, they are never oblique, but from ſome accidental change. Woodward and Ray talk of fiſſures, but in a general and confuſed manner,

manner, and they never mention them under the appellation of perpendicular fissures, because they imagined that they might be indifferently either oblique or perpendicular. No author has hitherto attempted to explain their origin, tho' it is apparent, as remarked in a former article, that they have been occasioned by the drying of the materials which compose the horizontal strata. In whatever manner this drying should happen, perpendicular fissures must have been a necessary consequence; for the matter of the horizontal strata could not be diminished in size, without splitting, at different distances, in a direction perpendicular to the strata themselves. Under perpendicular fissures, I comprehend, not only the natural cracks in rocks, but all those separations which have been effected by convulsive accidents. When a mass of rock has suffered any considerable motion, the fissures are sometimes placed obliquely; but it is because the mass itself is oblique; and the smallest attention to quarries of marble and lime-stone, or to great chains of rocks, will convince us, that the general direction of fissures is perpendicular to the strata in which they are found.

The bowels of mountains are chiefly composed of parallel strata of stones and rocks. Between the parallel strata, we often meet with beds of matter softer than stone; and the perpendicular fissures are filled with sand, crystals, metals, &c. The formation of these last bodies

dies is more recent than that of the horizontal strata in which sea-shells are found. The rains have gradually detached the sand and earth from the tops of mountains, and left the stones and rocks bare, which afford an opportunity of distinguishing with ease both the parallel strata and the perpendicular fissures. On the other hand, the rains and rivers have successively covered the plains with considerable quantities of earth, sand, gravel, and other bodies which are either soluble in, or easily divisible by water. Of these have been formed beds of tufa, of soft stone, of sand, of rounded gravel, and of earth mixed with vegetable substances. But these beds contain no sea-shells, or at most, but fragments of them, which have been detached from the mountains along with the earth and gravel. These recent beds should be carefully distinguished from the ancient and original strata, in which we almost universally find a greater number of entire shells placed in their natural situation.

- . In examining the internal order and distribution of the materials of a mountain, composed of common stone or calcinable lapidific matter, we generally find, after removing the vegetable soil, a bed of gravel, of the same nature and colour with the stones which predominate in the mountain; and, under the gravel, we meet with the solid rock. When the mountain is cut by a deep trench or *ravine*, the different banks or strata are easily distinguishable. Each horizontal

tal stratum is separated by a kind of joint or suture, which is likewise horizontal. These strata generally augment in thickness, in proportion to their depth or distance from the top of the mountain; and they are all divided, vertically, by perpendicular fissures. In general, the first stratum under the gravel, and even the second, are not only thinner than those which form the base of the mountain, but so much cut by perpendicular fissures, that small portions of them only have any coherence. Most of these fissures, which exactly resemble the cracks in earth that has been dried, gradually disappear as they descend, and, at the base of the mountain, where they cut the larger strata in a more regular and more perpendicular manner than those near the surface, their number is much smaller.

These strata of rock often extend, without interruption, to great distances. Stones of the same species likewise are almost uniformly found in opposite mountains, whether they be separated by a narrow neck or a valley; and the strata never entirely disappear, unless when the mountain terminates in a large and level plain. Sometimes we find, between the vegetable soil and the gravel, a stratum of marl, which communicates its colour, and other qualities, to the neighbouring beds: The perpendicular fissures in the inferior rocks are, in this case, filled with marl, where it acquires a hardness equal, in appearance, to that of the surrounding stone; but,

when exposed to the air, it splits, and becomes soft and ductile.

The beds of stone which compose the tops of mountains are generally soft and tender, but those near the base are exceedingly hard. The first is commonly white, and of a grain so fine as to be hardly perceptible. In proportion as they descend, the rocks become more compact, and have a better grain; and the lowest beds are not only harder than the superior ones, but are also more compact and heavy. Their grain is fine and brilliant; and they are often so brittle as to break as purely and neatly as flint.

The heart of a mountain, then, is composed of different strata of stones, which are harder or softer in proportion to their distance from the summit; and they are broad at the base, and sharp and narrow at the top. The last is, indeed, a necessary result of the first: For, as the stones grow harder as they descend, it is natural to think, that the currents, and other motions of the water, which scooped out the valleys, and formed the contours of the mountains, must have gradually consumed, by their lateral friction, the materials of which the mountains are composed; and that this consumption would be proportioned to the hardness or softness of the matter acted upon. But, as the upper strata are known to be softest, and as their density increases according as they approach the base, the mountains

tains must, of necessity, have assumed their present inclined, and somewhat conical figure. This is one great cause of the declivity of mountains; and it must always become more gentle, in proportion as the earth and gravel are brought down by the rain from their summits. For these reasons, the declivity of hills and mountains, composed of calcinable bodies, is less than that of those which consist of granite, or of flint in large masses. The latter generally rise almost perpendicularly to very great heights; because in these masses of vitrifiable matter, the superior, as well as the inferior strata, are extremely hard, and have presented nearly an equal resistance to the operation of the waters.

Though, in the tops of some hills which are flat, and pretty extensive, we find hard stone immediately under the vegetable soil; yet it should be remarked, that, in every example of this kind, what appears to be the summit of a hill is only a continuation of some more elevated hill in the neighbourhood, the upper strata, of which consist of soft, and the inferior strata of hard stone; and the hard stone found on the top of the first hill is only a continuation of the under strata of the higher hill.

Still, however, on the tops of hills which are not surmounted by higher grounds, the stone is mostly of a soft and friable nature; and hard stone cannot be had without digging to a considerable depth. It is between these layers of hard

hard stone only that marble is to be found; and it is variegated with different colours by metallic substances carried down by rain-water, and filtrated through the strata: And it is probable that, in every country which furnishes stones, marble would be found, if pits were dug to a sufficient depth: *Quoto enim, says Pliny, loco non suum marmor invenitur?* It is, in fact, a more common stone than is generally imagined, and differs from other stones only in the fineness of its grain, which renders it compact, and susceptible of a fine and brilliant polish.

Both the perpendicular fissures, and the horizontal joints of quarries, are often filled, or encrusted, with concretions, which are sometimes, transparent, and of regular figures, as crystals, and sometimes earthy and opaque. Water runs through the perpendicular fissures, and even penetrates the close texture of the stone itself. Stones which are porous imbibe water so copiously, that frost splits them in pieces. The rain-waters, by filtrating through different strata, are impregnated with a great variety of substances. They first sink through the perpendicular fissures; they then penetrate the strata of stone, and deposite in the horizontal joints, as well as in the perpendicular fissures, such matter as they collect in their course, and give rise to different concretions, according to the nature of these substances. For example, when the water filtrates through mark, clay, or soft stone, the mat-
ter

ter which it deposites is nothing but a fine pure marl, and commonly appears in the perpendicular fissures under the form of a porous, soft, white, light substance, known among naturalists under the name of *Lac Lunæ*, or *Medulla Saxi*.

When veins of water, charged with stony matter, run along the horizontal joints of soft stone or chalk, this matter adheres to the surface of the stones, and forms a white, scaly, light, and spongy crust, which, from its resemblance to the agaric, has been called *mineral agaric*. But, if the strata through which the water penetrates be hard stone, the filter being closer, the water it allows to pass will be impregnated with a stony matter more pure and homogeneous; and, consequently, the particles being capable of a more compact and intimate union, will form concretions, nearly of equal density with the stone itself, and somewhat transparent. In quarries of this kind, the surface of the stones are encrusted with undulated concretions, which entirely fill up the horizontal joints.

In grottos and cavities of rocks, which may be regarded as the basins or common sewers of the perpendicular fissures, the different directions of the veins of water give different forms to the concretions that result from them. These forms are generally wreathed, or resemble an inverted cone, attached to the roof of the cavern; or, rather, they are white, hollow cylinders, com-
posed

posed of concentric coats. The impregnated waters sometimes fall in drops upon the floor of the cavern, and form columns, and a thousand whimsical figures, to which naturalists have given the different appellations of *stalactites*, *stegmites*, *osteocollæ*, &c.

Lastly, When the concreting juices issue immediately from marble, or very hard stone, the lapidific matter is rather dissolved than suspended in the water, and it forms a kind of columns with triangular points, which are transparent, and consist of oblique coats. This substance is distinguished by the name of *spar* or *spalt*. It is transparent and colourless, except when the stone or marble through which it filtrates contains metallic particles. This spar is of equal hardness with the stone itself, and it dissolves in acids, and calcines with the same degree of heat. Hence it is evident, that spar is a true stone, and perfectly homogeneous. It may even be considered as a pure and elementary stone.

Most naturalists, however, consider this as a distinct substance, existing independent of stone: It is the lapidific or crystalline juice, which, in their estimation, not only cements the particles of common stone, but even those of flint. This juice, they allege, daily augments the density of stones by reiterated filtrations, and at last converts them into flint: When concreted into spar, it perpetually receives fresh supplies of still purer juice, which increases both its hardness

and its density, till it changes to the consistence of glass, then to that of crystal, and at last it is converted into genuine diamond.

But, on this supposition, Why does the lapidific juice produce stone in some provinces only, and nothing but flint in others? It may be said, that the one province is less ancient than the other, and that the juice has not had time sufficient to complete its natural operations. But in this there is not the shadow of probability. Besides, from whence does this juice proceed? If it gives rise to stones and flints, from whence does it derive its own origin? It is obvious, that it has no existence independent of those substances which alone can impart to the water that penetrates them, a petrifying quality that uniformly corresponds with their nature and peculiar properties. Thus, when it filtrates through stone, it produces spar; when it issues from flint, it forms crystal; and there are as many species of this juice as of bodies from which it proceeds. Experience confirms this account of the matter. The waters, which filtrate through quarries of common stone, form tender and calcinable concretions similar to the stones themselves. On the other hand, the waters which exude from granite or from flint, produce concretions hard and vitrifiable, and they have all the other properties of flint, as the former had all those of stone. In the same manner, the waters, which filtrate through mineral and metallic substances,

give rise to pyrites, marcasites, and metallic grains.

It was formerly remarked, that all matter might be divided into the two great classes of Vitriifiable and Calcinable. Clay and flint, marl and stone, may be regarded as the two extremes of each class, the intervals between which are filled with an almost infinite variety of mixts, that have always one or other of these substances for their basis.

The substances belonging to the first class can never acquire the properties of those of the latter. Stone, however ancient, will for ever be equally removed from the nature of flint, as clay is from that of marl. No known agent can ever force them from the circle of combinations peculiar to their nature. Places which produce marble and stone will always continue to do so, as infallibly as those that produce only sandstone, flint, and granite, will never produce limestone or marble.

• If we examine the order and distribution of the materials of a hill composed of vitriifiable substances, we shall generally find, under the vegetable soil, a stratum of clay, which is likewise a vitriifiable substance analogous to flint, and which, as already remarked, is only a decomposition of vitriifiable sand; or rather, we shall find, under the soil, a stratum of vitriifiable sand. This stratum of clay or of sand corresponds with the ~~bed of~~ gravel in hills consisting of calcinable matters.

matters. Below the stratum of clay or of sand, we meet with some beds of free-stone, which seldom exceed half a foot in thickness, and they are divided into small portions by perpendicular fissures. Under these are several strata of the same matter, and likewise beds of vitrifiable sand. In proportion as we descend, the free-stone is more dense, and its thickness increases. Below these, we find what I call *live-rock*, or *flint in large masses*, a substance so hard as to resist the file, and all kinds of acids, more powerfully than vitrifiable sand, or powder of glass, upon which aquafortis seems to have some effect. When struck with another hard body, it throws out sparks of fire, and exhales a penetrating sulphureous vapour. This flinty substance is commonly found along with beds of clay, of slate, of pit-coal, of vitrifiable sand; and it corresponds to the strata of hard stone and marble, which serve as the bases of hills that consist of calcinable matter.

The waters, in passing through the perpendicular fissures, and in penetrating the strata of vitrifiable sand, of free-stone, of clay, and of slate, are impregnated with the finest and most homogeneous particles of these substances, and produce various concretions, such as talc, asbestos, and other bodies which owe their existence to distillation through vitrifiable matter.

Flint, notwithstanding its hardness and density, has, like marble and common stone, its exu-

dations, from which result stalaćtites of different species, varying in transparency, colour, and configuration, according to the nature of the flint that produces them, and to the different metallic or heterogeneous particles it contains. Rock-crystal, all the precious stones, and even the diamond itself, may be regarded as stalaćtites of this kind. The flints in small masses, the strata or coats of which are generally concentric, are only stalaćtites or parasitical stones from the flints in large masses; and most of the fine opaque stones are nothing but species of flint. The substances produced by the vitrifiable class of bodies are not, as we have seen, so various as the concretions formed by those of the calcinable. Most of the concretions formed by flint are hard and precious stones; but those produced by calcareous stones are friable, and of no value.

Perpendicular fissures are found in flint-rocks as well as in stone. They are even frequently larger in flint, which proves this substance to be drier than stone. Both the hill consisting of calcinable, and that composed of vitrifiable matter, have clay or vitrifiable sand for their bases, which are the most commonly diffused matters of the globe, and which I regard as the lightest, being the scoriae of the vitrified matter that constitutes the interior parts of the earth. Thus all mountains as well as plains are founded either on clay or sands. We have seen, for example, in the pits of Amsterdam, and in that of Marly-la-ville,

la-ville, that vitrifiable sand was always the deepest stratum.

It may be observed, in most bare rocks, that the walls of perpendicular fissures, whether they be narrow or wide, correspond as exactly with each other as split pieces of wood. In the large quarries of Arabia, which consist mostly of granite, the perpendicular fissures are frequent; and, though some of them are 20 or 30 yards wide, the sides correspond exactly, and leave a deep cavity between them*. It is likewise common to find, in perpendicular fissures, shells divided into two pieces, each piece remaining attached to the opposite sides of the fissure; which proves, that these shells were deposited in the solid stratum before it was split†.

In some quarries mentioned by Mr. Shaw, the perpendicular fissures are exceedingly large; and for this reason, perhaps, they are less numerous. In quarries of granite and flint in large masses, blocks of stone may be raised, as the obelisks and columns at Rome, of 60, 80, 100, and 150 feet long, without the least interruption. It appears, that these vast blocks have been raised from the same quarry, and, like some species of free-stone, that they may be had of any given thickness. In other substances, the perpendicular fissures are very narrow, as in clay, in marl, and in chalk; and they are wider in

* See Shaw's Travels.

† See Woodward, p. 298

marble and hard stone. Some are imperceptible, because they have been filled with a matter nearly similar to that of the stone itself; but still they interrupt the continuity of the stones, and are called *hairs* by the workmen. I have often remarked, that these hairs in marble and stone differed from perpendicular fissures only in the separation of parts not being complete. These species of fissures are filled with a transparent matter, which is a true spar. In quarries of free-stone, the fissures are numerous, and considerably large, because rocks of this kind have often a less solid base than that which supports marble or lime-stone, the former generally resting upon a fine sand, and the latter upon clay. In many places, free-stone is not to be found in large masses; and in most quarries, where this stone is good, the blocks lie irregularly upon one another, in the form of cubes or parallelopipeds, as in the hills of Fontainebleau, which appear, at a distance, like the ruins of old buildings. This irregular disposition has been occasioned by the sandy foundation of these hills allowing the blocks to sink and tumble upon each other, especially where quarries have been formerly wrought, which has given rise to a great variety of fissures and intervals between the different blocks: And it may be remarked, in all countries abounding with sand and free-stone, that there are many fragments of rocks and large stones in the middle of the plains and valleys; and

and that, on the contrary, in countries abounding with marble and hard stone, these scattered fragments, which have rolled down from the hills, are exceedingly rare. This phænomenon is owing to the different solidities of the bases upon which these stones are supported, and to the extent of the banks of marble or lime-stone, which is always more considerable than that of free-stone.

P R O O F S

OF THE

THEORY OF THE EARTH.

A R T I C L E XVIII.

Of the Effects of Rains—Of Marshes, Subterraneous Wood and Waters.

IT has already been remarked, that rains, and the currents of water which they produce, continually detach, from the summits and sides of mountains, earth, gravel, &c. and carry them down to the plains; and that the rivers transport part of them to the sea. The plains, therefore, by fresh accumulations of matter, are perpetually rising higher; and the mountains, for the same reason, are constantly diminishing both in size and elevation. Of the sinking of mountains, Joseph Blancanus relates several facts which were publicly known in his time. The steeple of the village of Craich, in the county of Derby, was not visible in 1572, from

from a certain mountain, on account of a higher mountain which intervened; but 80 or 100 years afterwards, not only the steeple, but likewise part of the church, were visible from the same station. Dr. Plot gives a similar example of a mountain between Sibbertoft and Ashby, in the county of Northampton. Sand, earth, gravel, and small stones, are not only carried down by the rains, but they sometimes undermine and drive before them large rocks, which considerably diminish the height of mountains. In general, the rocks are pointed and perpendicular in proportion to the height and steepness of mountains. The rocks in high mountains are very straight and naked. The large fragments which appear in the valleys have been detached by the operation of water and of frosts. Thus sand and earth are not the only substances detached from mountains by the rains; they attack the hardest rocks, and carry down large fragments of them into the plains. At Nant-phrancon, in 1685, a part of a large rock, which was supported on a narrow base, being undermined by the waters, fell and split into a number of fragments, the largest of which made deep trenches in the plain, crossed a small river, and stopped on the other side. To similar accidents we must ascribe the origin of all those large stones which are found in valleys adjacent to mountains. This phenomenon, as formerly remarked, is more common in countries where the mountains

mountains are composed of sand and free-stone, than in those the mountains of which consist of clay and marble; because sand is a less solid basis than clay.

To give an idea of the quantity of earth detached from mountains by the rains, we shall quote a passage on this subject from Dr. Plot's natural history of Stafford. He remarks, that a great number of coins struck in the reign of Edward IV. *i. e.* 200 years ago, were found buried 18 feet below the surface: Hence, he concludes, that the earth, which is marshy where the coins were found, augments about a foot in eleven years, or an inch and a twelfth each year. A similar observation may be made on trees buried 17 feet below the surface, under which were found medals of Julius Cæsar. Thus, the soil of the plains is considerably augmented and elevated by the matters washed down from the mountains.

The sand, gravel, and earth carried down from the mountains into the plains, form beds which ought not to be confounded with the original strata of the globe. To the former belong the beds of tufa, of soft stone, and of sand and gravel which have been rounded by the operation of water. To these may be added those beds of stone which have been formed by a species of incrustation, none of which derive their origin from the motion or sediments of the sea. In these strata of tufa and of soft imperfect stones,

we find a number of different vegetables, leaves of trees, land or river-shells, and small terrestrial animals, but never sea-shells, or other productions of the ocean. This circumstance, joined to their want of solidity, evidently proves, that these strata have been superinduced upon the dry surface of the earth, and that they are more recent than those of marble and other stones, which contain sea-shells, and have been originally formed by the waters of the sea. Tufa, and other new stones, appear to be hard and solid when first dug out of the earth; but they soon dissolve after being exposed to the operation of the weather. Their substance is so different from that of true stone, that, when broken down in order to make sand of them, they change into a kind of dirty earth. The stalactites, and other stony concretions which Mr. Tournefort apprehended to be marbles that had vegetated, are not genuine stones. We have already shown, that the formation of tufa is not ancient; and that it is not entitled to be ranked with stones. Tufa is an imperfect substance, differing from stone or earth, but deriving its origin from both by the intervention of rain water, in the same manner as incrustations are formed by the waters of certain springs. Thus, the strata of these substances are not ancient; nor have they, like the other species, been formed by sediments from the waters of the ocean. The strata of turf are also recent, and have been produced by successive accumulations

tions of half corrupted trees and other vegetables, which owe their preservation to a bituminous earth. No production of the sea ever appears in any of these new strata. But, on the contrary, we find in them many vegetables, the bones of land-animals, and land and river-shells. In the meadows near Ashly, in the county of Northampton, for example, they find, several feet below the surface, snail-shells, plants, herbs, and several species of river-shells, well preserved; but not a single sea-shell appears*. All these new strata have been formed by the waters on the surface changing their channels, and diffusing themselves on all sides. Part of these waters penetrate the earth, and run along the fissures of rocks and stones. The reason why water is so seldom found in high countries, or on the tops of hills, is, because high grounds are generally composed of stones and rocks. To find water, therefore, we must cut through the rocks till we arrive at clay or firm earth. But, when the thickness of the rock is great, as in high mountains where the rocks are often 1000 feet high, it is impossible to pierce them to their base; and consequently it is impossible to find water in such situations. There are even extensive countries that afford no water, as in Arabia Petrea, which is a desert where no rains fall, where the surface of the earth is covered with burning sands, where there is hardly the appearance of any soil, and where nothing but a few sickly plants are pro-

* See Phil. Trans. Abridg. vol. iv. p: 27).

duced. In this miserable country, wells are so rare, that travellers enumerate only five between Cairo and Mount Sinai, and the water they contain is bitter and saltish.

When the superficial waters can find no outlets or channels, they form marshes and fens. The most celebrated fens in Europe are those of Russia at the source of the Tanais; and those of Savolaxia and Enafak in Finland: There are also considerable marshes in Holland, Westphalia, and other countries. In Asia are the marshes of the Euphrates, of Tartary, and of the Palus Meotis. However, marshes are less frequent in Asia and Africa than in Europe. But the whole plains of America may be regarded as one continued marsh; which is a greater proof of the modernness of this country, and of the scarcity of its inhabitants, than of their want of industry.

There are extensive fens in England, particularly in Lincolnshire, near the sea, which has lost a great quantity of land on one side, and gained as much on the other. In the ancient soil many trees are found buried under the new earth which has been transported and deposited by the water: The same phænomenon is common in the marshes of Scotland. Near Bruges in Flanders, in digging to the depth of 40 or 50 feet, a vast number of trees were found, as close to each other as they are in a forest. Their trunks, branches, and leaves were so well preserved, that their different species could be easily distinguished.

distinguished. About 500 years ago, the earth where these trees were found was covered with the sea; and, before this time, we have neither record nor tradition of its existence. It must, however, have been dry-land when the trees grew upon it. Thus the land, that, in some remote period, was firm, and covered with wood, has been overwhelmed with the waters of the sea, which, in the course of time, have deposited 40 or 50 feet of earth upon the ancient surface, and then retired. A number of subterraneous trees was likewise discovered at Youle in Yorkshire, near the river Humber. Some of them are so large as to be of use in building; and it is affirmed, that they are as durable as oak. The country-people cut them into long thin slices, and sell them in the neighbouring villages, where the inhabitants employ them for lighting their pipes. All these trees appear to be broken; and the trunks are separated from the roots, as if they had been thrown down by a hurricane or an inundation. The wood appears to be fir; it has the same smell when burnt, and makes the same kind of charcoal*. In the Isle of Man, there is a marsh called *Curragh*, about six miles long and three broad, where subterraneous fir-trees are found; and, though 18 or 20 feet below the surface, they stand firm on their roots†. These trees are common in the marshes and bogs

* See Phil. Transf. No. 228.

† See Ray's Discourses, p. 232.

of Somerset, Chester, Lancashire, and Stafford. In some places there are subterraneous trees which have been cut, sawed, and squared by the hands of men; and even axes, and other implements are often found near them. Between Birmingham and Bromley, in the county of Lincoln, there are hills of a fine light sand, which is blown about by the winds, and transported by the rains, leaving bare the roots of large firs, in which the impressions of the ax are still exceedingly apparent. These hills have unquestionably been formed, like downs, by successive accumulations of sand transported by the motions of the sea. Subterraneous trees are also frequent in the marshes of Holland, Friesland, and near Groningen, which abound in turfs.

Subterraneous trees are of different species, viz. firs, oaks, birch, beech, yew, hawthorn, willow, ash, &c. In the fens of Lincoln, along the river Ouse, and on Hatfield-chace in Yorkshire, these trees stand erect, as if they were growing in a forest. The oaks are extremely hard, and are used in building, where they are said to last long, which I think improbable, as all the specimens I have examined lose their solidity, after being dried and exposed to the air. The ashes are tender, and soon fall into dust. Some of these trees are evidently cut and sawed with instruments; and the hatchets, which are sometimes found along with them, resemble the knives formerly used in sacrifices. Beside trees,

we

we also meet with vast quantities of filberds, acorns, and fir-cones, in many other fens in England, Scotland, and Ireland, as well as in the marshes of France, Switzerland, Savoy, and Italy*.

For four miles round the town of Modena, whenever the earth is dug to the depth of 63 feet, the workmen pierce about five feet more with a boring instrument, through which the water rushes up with such impetuosity, that it fills the wells to the top, almost instantaneously. The water in these wells continues perpetually, and is neither augmented nor diminished by rains or drought. What is still more remarkable in this spot, whenever the workmen dig to the depth of 14 feet, they find the rubbish and ruins of an ancient city, paved streets, houses, and different pieces of Mosaic work. Below this, the earth is solid, and appears not to have been moved. Still lower, however, we find a moist soil mixed with vegetables; and, at the depth of 26 feet, entire trees, as filberds, with nuts upon them, and great quantities of branches and leaves. At 28 feet, there is a stratum of soft chalk, 11 feet thick, mixed with sea-shells; and after this we still meet with vegetables, leaves and branches of trees, till we arrive at the depth of 63 feet, where there is a stratum of sand mixed with gravel and shells, similar to those which appear on the coasts of Italy. These

* See Phil. Transf. Abridg. vol. iv. p. 218, &c.

ſucceſſive ſtrata lie always in the ſame order, wherever pits have been dug; and ſometimes the boring inſtrument falls in with the trunks of large trees, which the workmen pierce with great labour: They likewiſe meet with bones of animals, pit-coal, flints, and pieces of iron. Ramazzini, who relates theſe facts, thinks, that the gulf of Venice formerly extended beyond Modena, and that this land, in the progreſs of time, has been gradually formed by the rivers, aſſiſted, perhaps, by inundations of the ſea.

I will inſiſt no longer upon the varieties in the compoſition of new ſtrata. It is ſufficient to have ſhown that they have been produced by no other cauſe than the waters which run or are ſtagnant upon the ſurface, and that they are neither ſo hard nor ſo ſolid as the ancient ſtrata which were formed under the waters of the ocean.

P R O O F S

OF THE

THEORY OF THE EARTH.

A R T I C L E XIX.

Of the Changes of Land into Sea, and of Sea into Land.

FROM what has been remarked in article 1. 7. 8. and 9. it is apparent, that the terrestrial globe has undergone some great and general changes; and it is equally certain, from what has been delivered in the other articles, that the surface of the earth has suffered particular alterations. Though we are not sufficiently acquainted with the order or succession of these particular changes, we know the principal causes by which they were produced. We can even distinguish their different effects; and, if we were able to collect all the facts which natural and civil history afford concerning the revolu-

tions that have happened on the surface of the earth, our theory would unquestionably receive additional supports, and would be rendered still more satisfactory.

One of the principal causes of these revolutions is the motion of the sea, which has continued invariably the same in all ages; for, as the sun, the moon, the earth, the waters, the air, &c. have existed from the moment of creation, the effects of the tides, of the motion of the sea from east to west, of the currents, and of the winds, must have been felt for an equal time: And, even supposing the axis of the globe to have formerly had a different inclination, and that the continents, as well as the seas, were differently disposed, the motions of the ocean, and the causes and effects of the winds, would have remained unaltered. In whatever part of the globe the immense quantities of water which fill the ocean were collected, they would be subject to the same motions.

It was no sooner suspected that our continent might formerly have been the bottom of the sea, than the fact became incontestible. The spoils of the ocean found in every place, the horizontal position of the strata, and the corresponding angles of the hills and mountains, appeared to be convincing proofs; for, when we examine the plains, the valleys, and the hills, it is apparent, that the surface of the earth has been figured by the waters. When we descend into
the

the bowels of the earth, it is equally evident, that those stones which include sea-shells, have been formed by sediments deposited by the waters, since the sea-shells themselves are impregnated with the same matter that surrounds them. And, in fine, if we consider the corresponding angles of the hills and mountains, we cannot hesitate in pronouncing, that they received their configuration and direction from currents of the ocean. It is true, that, since the earth was first left uncovered with water, the original figure of its surface has been gradually changing: The mountains have diminished in height; the plains have been elevated; the angles of the hills have become more obtuse; those bodies which have been rolled along by the rivers have received a roundish figure; new beds of tufa, of soft stone, of gravel, &c. have been formed. But every thing has remained essentially the same. The ancient form is still recognisable; and I am persuaded, that every man may be convinced, by his own eyes, of the truth of all that has been advanced on this subject; and, that whoever has attended to the proofs I have given, must be fully satisfied, that the earth was formerly under the waters of the ocean, and that the surface which we now behold, received its configuration from the currents and movements of the sea.

We formerly remarked, that the principal motion of the sea is from east to west. The ocean, accordingly, seems to have gained from

the eastern coasts both of the Old and the New Continent, a space of no less than 500 leagues. For the proofs, we must refer to Art. IX. and shall here only add, that the direction of all straits which join two seas, is from east to west. The straits of Magellan, of Frobisher, of Hudson, of Ceylon, of the sea of Corea, and of Kamtschatka, lie all in this direction, and appear to have been formed by the irruption of the waters, which, being forcibly pushed from east to west, have opened these passages, where the waters still preserve a stronger current in this than in any other direction; for, in all straits of this kind, the tides are high and violent; but, in those situated on the western coasts, as that of Gibraltar, of Sunda, &c. the motion of the tides is almost imperceptible.

The inequalities at the bottom of the sea change the direction of the motion of the waters. These inequalities have originated from sediments and matters transported by the tides, or by other movements in the water: The tides are the principal and first, though not the only cause, which produced these inequalities. The wind is another cause; though its action begins at the surface, it agitates the whole mass to the greatest depths, as appears from particular bodies which are detached from the bottom of the sea, and thrown ashore during violent storms only.

It

It has already been mentioned, that, between the Tropics, and even some degrees beyond them, an east wind perpetually blows. This wind, which assists the general motion of the sea from east to west, is as ancient as the tides ; because it is occasioned by the rarefaction of the air produced by the heat of the sun. There are two combined causes, therefore, the operation of which is greatest in the equatorial regions : 1st, The tides, which are greatest in the southern latitudes; and, 2^d, The east winds, which constantly reign in these climates. These two causes have concurred, from the first formation of the earth, in producing a motion in the waters from east to west, and in agitating them more violently in this region of the globe than in any other. It is for this reason that we find between the Tropics the greatest inequalities upon the surface of the earth. That part of Africa which lies between these circles, is nothing but a group of different chains of mountains, which generally extend from east to west, as appears from the direction of the great rivers that traverse this unknown region. The same observation holds with regard to the countries both of Asia and America, which lie between the Tropics.

The general motion of the sea from east to west, combined with the tides, currents, and winds, produce a variety of effects, both on the bottom of the ocean, and on the coasts. Vare-

nus thinks it extremely probable, that gulfs and straits have been formed by reiterated efforts of the ocean against the land; that the gulfs of Arabia, of Bengal, and of Cambaya, have been produced by irruptions of the waters, as well as the straits between Sicily and Italy, between Ceylon and India, between Greece and Eubœa, &c.; that the probability of such irruptions, and of certain lands having been deserted by the sea, is strengthened by the scarcity of islands in the middle of great seas, and by their never appearing there in groups; that, in the immense space occupied by the Pacific Ocean, there are only two or three small islands near the centre of it; and that, in the vast Atlantic Ocean between Africa and Brasil, we find only the small islands of St. Helena and Ascension: But all islands lie near large continents, as those of the Archipelago, which approach the continents both of Europe and Asia; the Canaries are near Africa; the Indian islands lie near the eastern part of the continent of Asia; the Antilles lie off the coast of America; and the Azores alone lie at a considerable distance both from Africa and America.

The popular tradition among the inhabitants of Ceylon, that their island had been separated from the peninsula of India by an irruption of the sea, is extremely probable. The great number of rocks and shoals between the island of Sumatra and the continent demonstrate their
former

former union. The Malabarians affirm, that the Maldiva islands once made a part of the continent of India; and, in general, we may believe, without hesitation, that all the eastern islands have been separated from continents by irruptions of the ocean*.

The island of Great Britain appears to have been formerly a part of the continent; and that England was once joined to France, the narrowness of the strait, and the sameness of the strata of stone and of earth on the opposite sides, are a sufficient indication. • If we suppose, says Dr. Wallis, that France was connected to England by an isthmus between Calais and Dover, two tides would necessarily strike with violence against each side of it twice every twenty-four hours; and the operation of the sea, both on the east and west of this isthmus, would, in the course of time, gradually cut through such a narrow neck of land. The tides acting with violence not only against this isthmus, but also against the coasts of France and of England, must have carried away vast quantities of earth, sand, and clay, from every part on which the waves exerted their fury. Their course, however, being interrupted by the isthmus, they would not, as might be imagined, deposite their sediments upon its shores, but would transport ~~and~~ deposite them on the great plain which now

* See Varen. Geogr. p. 203. 217. and 220.

forms the marsh of Romney, and is four miles broad and eight long; for no man, who has ever seen this plain, can possibly doubt of its having been formerly covered with the sea, as, without the intervention of the dikes of Dimchurch, a great part of it would still be overflowed by the spring-tides.

The German sea would act in the same manner against this isthmus and against the coasts of England and Flanders, and would carry its sediments into Holland and Zeland, the soil of which was formerly under the waters, though it is now elevated 40 feet above them. On the English coast, the German sea must have occupied that large valley which commences at Sandwich, runs by Canterbury, Chatham, Chilham, and terminates at Ashford, a space of more than 20 miles. Here the land is much more elevated than it was in ancient times; for, at Chatham, the bones of an hyppopotamos were found buried at the depth of 17 feet, and likewise anchors of ships, and sea-shells.

Nothing is more apparent than that new lands are formed by the earth, sand, clay, &c. transported and deposited by the sea: For, in the island of Okney, which is adjacent to the marshy coast of Romney, there was a flat space of ground in continual danger of being overflowed by the river Rother; but this flat, in less than 60 years, has been considerably elevated by the accession
of

of fresh matter brought in by every tide. This river has, besides, deepened its channel so much, that its mouth, which, less than 50 years ago, was fordable by men, is now capable of receiving large vessels.

In the same manner has the bank of sand, which runs obliquely from the coast of Norfolk to that of Zeland, been formed. This bank is the place where the German and French seas encounter since the rupture of the isthmus; and it is here that the waters deposite the earth and sand which they carry off from the coasts. It is even probable that this bank of sand may, in a succession of ages, give rise to a new isthmus*.

It is extremely probable, says Mr. Ray, that the island of Great Britain was formerly joined to France: Whether it was separated by an earthquake, by an irruption of the ocean, or by the operation of men, we know not. But the former junction of Britain to the continent is apparent from the identity of the rocks and different strata, at the same elevation, on the opposite coasts; and from the similar extent of the rocks on each side, being both about six miles. The narrowness of this strait, which exceeds not 24 English miles, and its shallowness, when compared to the depth of the neighbouring sea, render it probable that England has been separated from France by some accident. To these proofs

* See Phil. Transf. Abridg. vol. iv. p. 227.

we might add, that wolves and bears formerly existed in this island : It is not probable that these animals could swim over, nor that such destructive creatures would be transported by men ; for, in general, the noxious animals of the continent are found in all those islands which are very near it, but never in those that are remote. This fact was remarked by the Spaniards when they arrived at America *.

In the reign of Henry I. of England, a part of Flanders was overflowed by an irruption of the sea. In 1446, more than 10,000 persons were drowned by a similar irruption in the territory of Dordrecht, and more than 100,000 round Dullart in Friseland and Zeland. In these two provinces, above 300 villages were overflowed. The tops of their towers and spires are still visible above the surface of the water.

From the coasts of France, England, Holland, and Germany, the sea has in many places retreated. Hubert Thomas, in his description of the country of Liege, assures us, that the walls of the city of Tongres were formerly surrounded by the sea, though it is now 35 leagues distant from that city. He gives several satisfactory reasons : Among others, he informs us, that, in his time, the iron rings, to which ships were fastened, still remained in the walls. The fens of Lincoln, of the island of Ely, and the Crau of Provence in France, may be regarded as

* See Ray's Discourses, p. 208.

lands abandoned by the sea, which has likewise, since the year 1665, retired considerably from the mouth of the Rhone. At the mouth of the Arno in Italy, a large quantity of land has been gained from the sea; and Ravenna, which was formerly a harbour, is no longer a sea-port. The whole of Holland appears to be new land: The surface of the ground is nearly on a level with the sea, although it has received daily elevations from the mud and earths transported by the Rhine, the Maese, &c.; for the soil of Holland was formerly, in many places, computed to be 50 feet below the level of the sea.

It has been alledged, that, in the year 860, a furious tempest drove such quantities of sand up on the coast, that the mouth of the Rhine near Catt was entirely blocked up; and that this river overflowed the whole country, overturned trees and houses, and at last emptied itself into the channel of the Maese. In 1421, another inundation separated the city of Dordrecht from the main land, overwhelmed 72 villages, and drowned 100,000 persons, beside a vast number of cattle. The dike of Iffel was broken down in 1638, by the ice-boards from the Rhine blocking up the passage of the water, which occasioned an opening in the dike of several fathoms, and a great part of the province was laid under water before the breach could be repaired. The province of ~~the~~ Zeland, in 1682, suffered a similar inundation, which drowned more than 30 villages; and an
amazing

amazing number of men and cattle perished, as the unfortunate event happened during the night. The loss would have been still greater, had not a south-east wind opposed the motion of the waves; for there was such a swell in the sea, that the water rose 18 feet above the highest ground in the province*.

The harbour of Hithe, in the county of Kent, is entirely blocked up, notwithstanding much labour and expence bestowed, on different occasions, to clear it from rubbish. For several miles round, we find an astonishing quantity of shells and other sea-bodies, which had been accumulated in ancient times, and which are now covered with soil, and afford excellent pasturage. The sea, on the other hand, often encroaches upon the land. The lands of Goodwin, for example, which formerly belonged to a Nobleman of that name, are now converted into sands, and are covered with the waters of the ocean. Thus the sea gains upon some coasts, and loses upon others, according to their different situations and circumstances†.

Upon Mount Stella, in Portugal, there is a lake, in which are found the wrecks of ships, though this mountain is 12 leagues distant from the sea‡. Sabinus, in his commentary upon Ovid's *Metamorphoses*, tells us, that, in the year

* See les Voyag. hist. de l'Europe, tom. v. p. 70.

† See Phil. Trans. Abridg. vol. iv. p. 234.

‡ See Gordon's Geog. Gram. p. 149.

1460, a ship, with its anchors, were found in one of the Alpine mines.

These changes of sea into land, and of land into sea, are not peculiar to Europe. The other parts of the globe, if properly investigated, would furnish more striking and numerous examples.

Calecut was formerly a celebrated city, and the capital of a kingdom of that name. It is now reduced to an inconsiderable town, ill-built, and almost deserted. The sea, which, for a century past, has gained greatly upon this coast, now covers most of the ancient city. Ships moor upon its ruins, and the port is choaked up with a number of rocks, upon which many vessels have been wrecked*.

The province of Yucatan, a peninsula in the Gulf of Mexico, was formerly a part of the sea. This neck of land stretches about 100 leagues in length, and is no where above 25 leagues broad. The air is hot and moist. The earth furnishes plenty of water, though, in so large a country, there are neither rivers nor brooks; and, when pits are dug, such multitudes of shells every where appear, as leave no room for doubting that this whole tract of land was formerly a part of the ocean.

It is a tradition among the inhabitants of Malabar, that the Maldiva islands originally belonged to the continent of India, and that they were detached from it by the violence of the ocean.

* See *Lettres Edifiantes*, recueil ii. p. 187.

The number of these islands is so great, and they are separated by such narrow channels, that the bow-sprits of vessels in passing, drive off leaves from the trees on each side; and, in some places, a vigorous man, by laying hold of a branch, may leap into another island*. The cocoa trees found at the bottom of the sea, is a farther proof that the Maldivas formerly belonged to the continent.

The island of Ceylon, those of Rammanakoiel, and many other islands, it is believed, were also disjoined from the continent by currents, which, in many places of the Indian sea, are extremely rapid†. It is certain, however, that the sea has encroached 30 or 40 leagues on the north-east coast of Ceylon.

The sea appears to have lately abandoned many of the promontories and islands of America. We have already remarked, that the territory of Jucatan is full of shells. The same phenomenon takes place in the low grounds of Martinico and the other Antilles. The inhabitants distinguish the earth below the surface by the name of *lime*; because they make lime of the shells, great banks of which lie immediately under the vegetable soil‡.

There are some lands which the sea alternately covers and leaves bare, as happens in several islands

* See *Voyages des Hollandois aux Indes Orientales*, p. 274.

† *Ibid.* vol. iv. p. 485.

‡ See *Nouv. Voyages aux Îles de l'Amérique*.

Norway, Scotland, the Maldiva's, the gulf of Cambaya, &c. The Baltic sea has gradually gained a great part of Pomerania; and it has covered and destroyed the celebrated port of Vineta. In the same manner, the Norwegian sea has advanced into the continent, and formed several islands. The German sea has encroached upon Holland, near Catt, to such a degree, that the ruins of an ancient Roman citadel, which was formerly situated on the coast, lie now at a considerable distance in the sea. The marshy ground in the island of Ely, and the Crau of Province, are, on the contrary, lands which the sea has deserted. The Downs have been formed by accumulations of sand, earth, and shells successively driven upon the coasts by winds blowing from the sea. For example, on the west coasts of France, Spain, and Africa, a violent west wind reigns, by which the waters are pushed with violence against the shores; and downs, accordingly, are frequent on these coasts. The east winds, in the same manner, when they continue long, drive the waters so forcibly from the coasts of Syria and Phœnicia, that large chains of rocks, which are covered during the west winds, are left dry. Besides, downs are not composed of stones and marble, like the mountains which have been formed in the bottom of the ocean, because they have not remained long enough under the waters. That the waters of the sea possess a petrifying power, and that

the stones formed in the earth are very different from those formed at the bottom of the ocean, is fully evinced in my discourse on minerals.

Since finishing my theory of the earth, which was composed in the year 1744, I have perused M. Barrere's dissertation on the origin of figured stones. It gave me peculiar satisfaction to find that the ideas of this accomplished naturalist, concerning the formation of downs, and the duration of the sea upon the surface of the earth which we inhabit, exactly corresponded with my own. Aiguis-mortes, which is now more than a league and a half from the sea, was a port in the time of St. Louis. Psalmodi was an island in the year 815; and it is now more than two leagues from the sea. The same change has happened at Maguelone. The greatest part of the vineyard of Agde was covered, about 40 years ago, with the waters of the sea. In Spain, the sea, within these few years, has retired considerably from Blanes, from Badalona, from the environs of the river Vobregat, from Cape Tortosa along the coast of Valencia, &c.

The sea may form hills and mountains, 1. By transporting earth, slime, sand, and shells from one place to another: 2. By depositing sediments composed of small particles detached from the bottom and from the coasts: And, *lastly*, hills and downs may be formed by sand and other particles driven against the coasts by particular winds; these are gradually deserted by the sea;
and

and become parts of the dry land. The downs of Flanders and Holland are of this kind. They consist of small elevations or hills, composed of sand and shells which have been blown from the sea upon the coasts. M. Barrere gives another example, which merits observation. ‘ The sea,’ he remarks, ‘ by its motion, detaches immense quantities of plants, sand, shells, and slime, from its bottom, which are continually pushed by the winds and the waves towards the coasts. The perpetual repetition of this operation must give rise to gradual accumulations of new strata, which elevate the earth, produce downs and hills, enlarge the land; and confine the sea within narrower bounds. ’

‘ It is apparent that new strata of different materials must have been formed by the constant attrition of the waters, by the deposition of sediments, and by other causes, the operation of which has been co-eval with the existence of the globe itself. Of this we have a remarkable proof in the different strata of fossil shells, and other sea bodies, found at Rouffillon near the village of Naffiac, which is 7 or 8 leagues from the sea. These beds of shells, which incline at different angles from west to east, are divided from each other by strata of earth and sand sometimes of a foot and a half, and sometimes of two or three feet in thickness. In dry weather they seem as if sprinkled over with salt, and form a chain of hillocks from 25 to

‘ 30 fathoms high. A long chain of hillocks of
 ‘ such a height could not be formed at once,
 ‘ but gradually, and by a long succession of time.
 ‘ Effects somewhat similar might have been pro-
 ‘ duced by an universal deluge. But, in this
 ‘ case, the different beds of fossil shells, instead
 ‘ of preserving a regular form, would have been
 ‘ blended together without any order.’

I entirely agree with the sentiments of M. Barrere, except as to the formation of mountains, which cannot be ascribed solely to those causes which increase the land, and diminish the boundaries of the ocean. On the contrary, I can produce several convincing arguments to prove that most of those eminences, which appear on the surface of the earth, have actually received their original formation in the sea itself: 1. Because they have corresponding angles, which necessarily imply the cause we have assigned, namely, the motion of the currents. 2. Because downs and hills, which have originated from materials thrown upon the coasts, are not, like common hills, composed of marble and hard stones. Besides, the shells found in the former are only in the fossil state; but those in the latter are entirely petrified. Neither is the position of the strata equally horizontal in downs, as in the hills composed of marble and hard stone. They are more or less inclined, as in the hills of Naffiac. On the contrary, in the hills and mountains formed by sediments under.

under the waters of the sea, the strata are always parallel, and often horizontal; and the shells and other matter of them are completely petrified. I despair not of being able to prove, that the marbles and other calcareous bodies, which are almost all composed of madrepores, asteroites, and shells, have acquired their density and perfection at the bottom of the ocean. But the tufas, soft stones, incrustations, stalactites, &c. which are likewise calcinable, and have been formed since the earth was left dry, can never acquire the degree of density and of petrification peculiar to marble and other hard stones.

The remarks of M. Saulmon, concerning the *galets*, which are found in many places, may be seen in the history of the French Academy, *anno* 1707. These *galets* are round, flat, finely polished pieces of flint, thrown out by the sea upon the coasts. At Bayeux, and at Prutel, which is a league from the sea, *galets* are found in digging pits and wells. The mountains of Bonneuil, of Bròie, and of Quesnoy, which are 18 leagues distant from the sea, are covered with *galets*. They are also found in the valley of Clermont in Beauvois. M. Saulmon farther informs us, that a hole, 16 feet in length, was pierced horizontally into the high beach of Trefport, which consists of a soft earth; and that, in the space of 30 years, it was entirely obliterated by the sea. Supposing the sea to encroach

uniformly upon this shore, it will gain half a league in 12,000 years.

The motions of the sea, therefore, must be regarded as the principal cause of all those changes which have already happened, and of those which are daily produced upon the surface of the earth. But there are other causes, which, though less considerable, have some effect in changing the superficial parts of this globe. The rivers, the brooks, the melting of snows, the torrents, the frosts, &c. have given rise to many alterations. The rains have diminished the height of the mountains; the rivers and brooks have elevated the plains, and dammed up the sea at their mouths; the torrents and the melting of snows have scooped out deep ravines or furrows in the valleys and narrow passages between the mountains; the frosts have split rocks, and detached them from their original stations: Innumerable examples of revolutions produced by all these causes might be given. Varenius tells us, that the rivers transport into the sea vast quantities of earth, and deposite them at greater or lesser distances from the shore, in proportion to the rapidity of their currents. These portions of earth fall to the bottom, and first form small banks, which, by constant accessions, become shoals, and at last appear in the form of fertile and habitable islands. It is in this manner that the islands in the Nile, those in the river St. Lawrence, the island of Landa, situated near the
mouth

mouth of the river Coanza, on the coast of Africa, the Norwegian islands, &c. have received their existence*. To these may be added the island of Trong-ming in China, which has been gradually formed by matters brought down by the river Nankin, and deposited near its mouth. This island is more than 20 leagues in length, and from 5 to 6 in breadth†.

The Po, the Trento, and other rivers of Italy, bring down such quantities of earth into the *lagunes* of Venice, especially in the time of inundations, that they must be gradually filled up. Many parts of them are already dry during the ebb tide; and there is in them no depth of water, except in the canals, which are supported at an immense expence.

Large sand-banks are thrown up at the mouths of the Nile, of the Ganges, of the Indus, of the Plata, and of many other rivers. La Loubere, in his voyage to Siam, informs us, that the banks of sand and of earth augment daily, at the mouths of the great rivers of Asia, and to such a degree that the navigation of them becomes every hour more difficult, and will soon be impracticable. The same observation applies to the great rivers of Europe, and especially to the Wolga, which empties itself by more than 70 mouths into the Caspian, and to the Danube, which runs into the Black Sea by seven mouths, &c.

* See Varen. Geogr. p. 214.

† See Lettres Edifiant. rec. xi. p. 234.

As it seldom rains in Egypt, the regular inundations of the Nile proceed from the torrents which fall into it from Ethiopia. It brings down vast quantities of mud, which it deposits annually not only upon the soil of Egypt, but throws it to great distances into the sea, where it is laying the foundations of a new country, which must arise, in the course of time, out of the bosom of the ocean; for, upon founding at the distance of 20 leagues from the coast, the mud of the Nile is found at the bottom of the sea; and every year it receives fresh accumulations. The Lower Egypt, now called the *Delta*, was formerly a bay*. Homer tells us, that the island of Pharos was a day and a night's voyage from Egypt; and now it is almost contiguous to the land. The soil of Egypt is not every where of an equal depth; it grows thinner the farther we remove from the sea. Near the banks of the Nile, there are sometimes more than 30 feet of good soil; but at the extremity of the inundation, there are not, perhaps, above 7 inches. All the cities of the Lower Egypt have been built upon artificial eminences†. The town of Damietta, which is now ten miles from the sea, was a part of the ocean in the year 1243. The town of Fooah, which, 300 years ago, was situated at the mouth of the Canopic branch of the Nile, is now 7 miles distant from it. Within

* See Diodor. Sic. lib. iii. Aristot. de Meteor. lib. i. cap. 14. Herodot. § 4, 5, &c.

† See Shaw's Travels.

40 years, the sea has retired half a league from Rosetta, &c.*

Many changes have also taken place at the mouths of the great rivers of America, and even in those which have been but lately discovered. Charlevoix tells us, that at the mouth of the Mississippi, below New Orleans, the land runs out into a point, which appears not to be very ancient; because, wherever the earth is dug, plenty of water is found; and besides, the many little islands which have recently appeared in all the mouths of this river, leave no room to doubt that this point of land was formed in the same manner. It is certain, says he, that when M. Salle sailed down the Mississippi to the sea, the mouth of this river was considerably different from what it is now.

The nearer, he adds, we approach the sea, this difference becomes the more conspicuous. There is no water in most of the small channels cut in the bar by the river. These channels are greatly multiplied by the trees brought down by the current. A single tree, with its branches and roots, when stopped in a shallow part of the river, will entangle a thousand. I have seen, says he, 200 leagues from New Orleans, different collections of trees, any one of which would fill all the wood-yards in Paris. Nothing can disentangle them. The mud brought down by the river serves as a cement, and gradually

* See Shaw's Travels.

covers them. Every inundation leaves a new stratum; and, in a few years, plants and shrubs begin to grow. It is in this manner that most points of land and islands, which so often change the course of rivers, are originally produced.

All the revolutions, however, produced by rivers, are very slow, and become not considerable till after a long course of years. But those which are occasioned by inundations or earthquakes are sudden, and almost instantaneous. According to the *Timæus* of Plato, we are assured by the ancient priests of Egypt, 600 years before the birth of Christ, that there existed an island beyond the Pillars of Hercules, called *Atlantis*, which was larger than both Asia and Lybia taken together; and that this great island was sunk under the waters of the ocean by a terrible earthquake. ‘ Traditur Atheniensis civitas restitisse olim innumeris hostium copiis quæ, ex Atlantico mari profectæ, propè cunctam Europam Asiamque obsederunt; tunc enim fretum illud navigabile, habens in ore et quasi vestibulo ejus insulam quam Herculis Columnas cognominant: Ferturque insula illa Lybiâ simul et Asiâ Major fuisse, per quam ad alias proximas insulas patebat aditus, atque ex insulis ad omnem continentem è conspectu jacentem verò mari vicinam; sed intrà os ipsum portus. angusto sinu traditur, pelagus illud verum mare, terra quoque ille verè erat continens, &c. Post hæc ingenti terræ motu jugique .

‘ gique diei unius et noctis illuvione factum est,
 ‘ ut terra dehiscens omnes illos bellicosos absor-
 ‘ beret, et Atlantis insula sub vasto gurgite mer-
 ‘ geretur.’ *Plato in Timæo.* This ancient tra-
 dition is not devoid of probability. The lands
 swallowed up by the waters were, perhaps, those
 which united Ireland to the Azores, and the
 Azores to the continent of America; for, in
 Ireland, there are the same fossils, the same shells,
 and the same sea-bodies, as appear in America;
 and some of them are found in no other ~~part~~ part of
 Europe.

Two evidences are mentioned by Eusebius on
 the subject of deluges: The one is Melo, who
 affirms, that all the plains of Syria were form-
 erly laid under water: The other is Abidenus,
 who says, that in the reign of King Sisithrus,
 there was a great deluge, which had been pre-
 dicted by Saturn. Plutarch *De Solertia Anima-*
lium, Ovid, and other mythologists, describe the
 deluge of Deucalion, which happened, they say,
 in Thessaly, about 700 years after the universal
 deluge. It is also alleged, that there was a
 still more ancient deluge in Attica, during the
 time of Ogiges, about 230 years before that of
 Deucalion. In the year 1095, a deluge in Syria
 drowned a prodigious number of people*. In
 1164, a deluge in Friesland covered the whole
 environs of the coasts, and drowned several
 thousands of the inhabitants†. Another inun-

* See Alsted. Chron. chap. 25.

† See Krank, lib. v. c. 4.

dation, in 1218, destroyed 100,000 men. Of inundations there are many other examples.

Impetuous winds may be regarded as a third cause of changes on the surface of the globe. They not only give rise to downs and hills along the sea-coasts, but they often arrest rivers, make them regorge, and change their directions. They carry off cultivated lands, tear up trees, overturn houses, and cover whole countries with sand. Upon the coast of Brittany, in France, we have an example of these inundations of sand: The history of the Academy, ann. 1722, describes it in the following terms:

‘ In the environs of St. Paul de Leon, in
 ‘ Lower Brittany, there is a province on the sea-
 ‘ coast, which, before the year 1666, was inha-
 ‘ bited; but now is totally deserted, on account
 ‘ of the sand, which has covered it to the depth
 ‘ of 20 feet, and which daily gains ground.
 ‘ Reckoning from the above period, the sand
 ‘ has advanced about 6 leagues into the country;
 ‘ and it is now within half a league of St. Paul,
 ‘ and that town must probably soon be deserted.
 ‘ The tops of steeples, and of some chimneys,
 ‘ still appear above this ocean of sand. The
 ‘ inhabitants, however, have always had leisure
 ‘ to quit their possessions in safety. p. 7.

‘ This calamity is augmented by an east, or a
 north wind, which elevate this fine sand, and
 carry it in such quantities, and with such ra-
 pidity, that M. Deslandes, to whom the Aca-
 demy,

‘ demy are indebted for the observation, when
 ‘ walking in this country during an east wind,
 ‘ found himself obliged to shake his hat and his
 ‘ garments from time to time, on account of the
 ‘ great weight of sand with which they were
 ‘ loaded. Besides, when the wind is violent, it
 ‘ carries the sand over a small arm of the sea as
 ‘ far as Roscof, a port much frequented by fo-
 ‘ reign vessels; and the sand accumulates in the
 ‘ streets of this village to the height of two feet,
 ‘ which obliges the inhabitants to drive it ~~off~~ in
 ‘ waggons. It may be further remarked, that
 ‘ the sand is mixed with furruginous particles,
 ‘ which are recognisable by the magnet.

‘ The coast which furnishes this sand extends
 ‘ from St. Paul to Plouefcat, a space of more than
 ‘ four leagues; and it is nearly on a level with
 ‘ the sea when the tide is full. It is situated in
 ‘ such a manner that the east and north-east
 ‘ winds only can blow the sand in upon the
 ‘ country. It is easy to conceive how sand car-
 ‘ ried and accumulated into any place by the
 ‘ wind, may again be taken up by the same
 ‘ wind, and carried still farther. Thus the sand
 ‘ may continue advancing, and covering new
 ‘ lands, as long as the magazine from which it
 ‘ originally proceeds shall remain unexhausted;
 ‘ for, if the fountain were once dried up, the
 ‘ sand, by advancing, would diminish ~~its~~ depth,
 ‘ and its destructive consequences would gradu-
 ‘ ally

ally decay. But it is not improbable that the sea may long continue to supply fresh sand, and keep this baneful magazine in a condition to do perpetual mischief.

This disaster is not of an old date. Perhaps it was not till lately that the place was sufficiently stored to allow great quantities of sand to be carried off; or, perhaps, it has but recently been left uncovered by the waters. This coast has undergone some change. At present, the sea, at full tide, reaches half a league on this side of certain rocks, which it formerly never passed.

This miserable province justifies what has been related, both by ancient and by modern travellers, that whole cities, and even vast armies, have been buried by tempests of sand in the deserts of Arabia.

Mr. Shaw relates, that the ports of Laodicea, Tortosa, Rowadsa, Tripoly, Tyre, Acra, and Jaffa, are blocked up with sand transported by the high waves which rise on that part of the coast of the Mediterranean, when the west winds blow with violence*.

It is needless to give more examples of alterations on the surface of this globe. The fire, the air, and the waters, produce continual changes, which, in a succession of ages, become considerable. The sea and the land not only

* See Shaw's Travels.

change places from the effects of general and stated periodic laws, but a number of revolutions are occasioned by particular and accidental causes, as earthquakes, inundations, sinkings of mountains, &c. Thus the surface of the earth, which we regard as the most permanent of all things, is subjected, like the rest of nature, to perpetual vicissitudes.

C O N C L U S I O N .

FROM the proofs delivered in Art. VII. and VIII. it appears to be an established fact, that the whole surface of what is now dry land, was formerly buried under the waters of the ocean. It is equally clear, from Art. XII. ~~that~~ the flux and reflux, and other movements of the ocean, perpetually detach from the coasts and from the bottom of the sea, shells, and matter of every species; and that these are deposited in other places in the form of sediments, and give rise to the horizontal strata which every where appear. In the IX. Art. we have proved, that the inequalities on the surface of the globe have been occasioned by the motion of the waters of the sea; and that the mountains received their original formation from successive accumulations of sediments. It is likewise evident, from Art. XIII. that the currents which first followed the direction of these inequalities, afterwards bestowed on them their present figure, namely, their alternate and corresponding angles. From Art. VIII. and XVIII. it appears, that most of the matters detached from the coasts and from the bottom of the sea were, when deposited in sediments, in the form of a fine im-
palpable

palpable powder, which entirely filled the cavities of shells, whether this powder was of the same nature, or only analogous to the matter of which the shells were composed. It is undeniable, from Art. XVII. that the horizontal strata, which have been formed by successive accumulations of sediments, and which at first were soft and ductile, acquired density and compactness in proportion as they dried; and that the perpendicular fissures in the strata derived their origin from the act of drying.

After perusing Art. X. XI. XIV. XV, XVI. XVII. XVIII. and XIX. we must be convinced, that the surface of the earth has been disfigured by many revolutions and particular vicissitudes, arising from the operation of the waters, and the effects of rains, frost, rivers, winds, subterraneous fires, earthquakes, inundations, &c. and, consequently, that the sea has alternately changed places with the dry land, especially in the first ages after the creation, when terrestrial substances were much softer than they are at present. It must however be acknowledged, that our judgment concerning the succession of natural revolutions cannot fail to be very imperfect; that we are still less competent judges of those changes which owe their birth to fortuitous events; and that the defect of historic records deprives us of the knowledge of particular facts. We desiderate both time and experience. We never consider, that, though our existence here

be extremely limited, Nature proceeds in her course. We are ambitious of condensing into our momentary duration both the past and the future, without reflecting that human life is only a point of time, a single fact in the history of the operations of God.

END OF THE FIRST VOLUME.

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